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THE EFFECTS OF CIRCUIT TRAINING USING HYDRAULIC RESISTIVE EXERCISE ON AEROBIC POWER, STRENGTH AND ENDURANCE

by

S. WAYNE LEE

A THESIS

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.....
Supervisor

.....

.....

Date . May. 9th. 1983

DEDICATION

To Claire - the one who has been
and will always be my advisor,
my confidante, my friend, my wife . . .
Thank you for your love, constant
support and inspiration.
- plus que hier, moins que demain -

ABSTRACT

Fifteen volunteer male subjects participated in an eight week program using hydraulic resistive equipment. They were compared to a normal group consisting of fifteen male subjects. Each subject underwent a pre-test and post-test designed to measure aerobic power, muscular strength at two pre-selected angular velocities and muscular endurance.

The experimental group showed a 27 percent ($p < 0.005$) improvement in maximal oxygen uptake while the normal group did not change in pre- to post-test. The difference between the post-test means was significant ($p < 0.05$). When the data was normalized the Δ percentage change was significant ($p < 0.001$). Similar results (26 percent, $p < 0.05$) were noted when the data was expressed independent of body weight (e.g., liters/min of oxygen). The normalized Δ percentage change was significant ($p < 0.001$). Minute ventilation improved 16 percent from pre- to post-test which was not significant; however, the difference between post-test means was significant ($p < 0.05$). The normalized data was significant ($p < 0.05$).

Muscular strength was measured during maximal knee flexion/extension of the right leg at angular velocities of 30° and 60° per second. At 30° per second, the experimental group improved 20 percent ($p < 0.005$) during extension and 23 percent ($p < 0.005$) during flexion in pre- to post-test means. The normal group demonstrated comparable improvement ($p < 0.01$). As a result the post-test means were not significantly different. The normalized Δ percentage change was significant ($p < 0.01$) for extension. At 60° per second the experimental group improved 19 percent ($p < 0.01$) during extension and 28 percent ($p < 0.001$) during

flexion in pre- to post-test means. Improvements in the normal group resulted in nonsignificant (N.S.) post-test means. The normalized Δ percentage change was also not significant for extension or flexion.

Muscular endurance was measured in terms of total work and total work per second at an angular velocity of 180° per second until 50 percent drop-off. In terms of total work, the experimental group showed a 29 percent ($p < 0.001$) improvement in extension and a 35 percent ($p < 0.001$) improvement in flexion. The normal group did not change significantly. When the data was normalized the Δ percentage change was significant ($p < 0.05$) for flexion and not significant for extension. In total work per second, the training group improved 39 percent ($p < 0.001$) in extension and 47 percent ($p < 0.001$) in flexion in pre- to post-test. The normal group did not change in extension but had significant changes ($p < 0.05$) for flexion. Post-test means were significant ($p < 0.05$) for extension and flexion. The normalized data demonstrated significant ($p < 0.01$) for extension and flexion.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Traditional weight lifting has not been considered one of the more effective forms of exercise with respect to improving cardio-respiratory function. Keul (1) has indicated that this is due to the relatively low heart rates which occur during traditional high resistance, low repetition weight lifting regimens. However, Byrd et al. (2) demonstrated that the cumulative effect of repeated lifting during weight training programs can produce heart rates in excess of those which have served as an adequate stimulus for eliciting a training response during running programs (3, 4). Byrd et al. concludes that the reported lack of cardiovascular adaptations in previous weight training studies might have been the result of the limited training program duration or to the use of inappropriate exercise tests to evaluate the cardiovascular effects of weight training.

Circuit weight training is a form of physical conditioning that combines the benefits of weight lifting and the cardio-respiratory gains associated with circuit training (5). Fox (3) described it as an effective training technique for improving muscular strength, muscular endurance and to a lesser extent, flexibility and cardio-respiratory endurance. The influence of circuit weight training on cardio-respiratory endurance has aroused a great deal of interest among researchers (6, 7, 8, 9, 10). These studies have reported conflicting results, but, for the most part, have concluded that weight lifting was not an effective means of improving cardio-respiratory efficiency.

Other research has been carried out on resistance training equipment emphasizing isokinetic exercise (11, 12, 13). Several variable resistance exercise systems have been developed in an effort to make the best practical use of training principles. The Hydra-Gym† hydraulic resistive exercise apparatus is a recent design. Hydraulic resistive apparatus provide a self accommodating variable, isokinetic-like resistance at any joint angle throughout a range of motion and at whatever speed the user moves. This is made possible by the use of hydraulic cylinders. The hydraulic cylinders with ranked settings "1" through "6" can be adjusted to vary the resistance. This is done by changing the aperture size through which hydraulic fluid must flow as the lever arm moves; the faster the lever arm moves, the greater the resistance. The manufacturer (14) claims that while the valves are pre-set, the rate at which the limb moves against the resistance of the cylinder is determined not so much by the machine as it is by the contractile properties of the user's muscle fibers and the muscle groups that those fibers constitute. Consequently, at a given valve setting, if the user attempts to move as rapidly as possible, optimal resistance overload with each repetition should occur. Even as the muscle fatigues, the effective resistance overload remains the same. Thus the user achieves optimal resistance overload at the beginning of the set when the muscles are at the peak of their energy level and also at the end of the set when the muscles are fatigued. The basic differences between hydraulic resistance and isokinetic resistance is that the hydraulic resistance machine is not pre-set to a constant velocity as in an

---

†Hydra-Gym Canada Ltd., 25 Woodbine Courts, Sherwood Park, Alberta, T8A 4B1.

isokinetic exerciser. The manufacturer describes the exercise as omni-kinetic - a form of variable resistance exercise that allows for optimal self accommodating resistance and which is dependent upon the muscles contractile properties.

This system may have practical advantages in conditioning the cardio-respiratory system since anything from low power output with small muscle groups to ultra-high concurrent power outputs with larger muscle groups can be achieved (11). For example, a training program designed as a circuit using hydraulic resistive equipment and minimum rest period between stations may stimulate cardio-respiratory improvement as well as muscular strength and endurance improvement.

Statement of the Purpose

The primary purpose of this study was to critically examine the training effect of an eight week program of circuit training using hydraulic resistive apparatus on a commonly used indicator of cardio-respiratory fitness maximal oxygen uptake (VO_2max).

A secondary purpose of the study was to examine changes in muscular strength and muscular endurance of the quadricep and hamstring muscle groups as a result of eight weeks of training.

Significance of the Study

The present study examined the effects of an eight week program of hydraulic resistive exercise on cardio-respiratory fitness, muscular strength and muscular endurance. This may have practical significance as a training program which may attend to several of the components of physical fitness when considering the varying circumstances under which people are employed in the Canadian Forces. An example of this may be in the Navy or in isolated circumstances where limited space and

inhospitable weather conditions become a deterrent to physical activity.

Limitations

The investigator could not control:

1. the subjects' motivation during testing and training;
2. the subjects' diet during the course of the study.

Delimitations

The study was restricted to:

1. thirty male subjects, 18-35 years of age;
2. specific training program and equipment (see Methods).

Operational Definitions

Maximal Oxygen Uptake: refers to the maximal volume of oxygen which is consumed per minute (liters/min or ml/kg/min) during a progressive exercise. During a continuous bicycle ergometer test, it was a point where there was an increase of less than 80 ml/min in VO_2 measurement in two successive readings or when the subject could no longer continue due to fatigue.

Circuit Training: refers to a specified number of exercise stations where exercises are performed in a specified order and time using hydraulic resistive units (see Method).

Muscular Strength: refers to the force that a muscle or muscle group exerts against a resistance in one maximal effort as measured on Cybex II during knee extension and flexion at 30° and 60° per second angular velocity (see Methods).

Muscle Endurance: refers to the ability of the muscle to contract continuously and/or repeatedly against a constant resistance, while moving through a range of motion as measured on Cybex II during

knee extension and flexion, at 180° per second angular velocity until 50 percent of the maximal torque volume was reached (see Methods).

CHAPTER II

METHODOLOGY

Subjects

The subjects were 30 male military personnel from Canadian Forces Base Edmonton. The majority of the subjects were fire fighters or other support personnel who volunteered to participate in this project. The subjects ranged in age from 18-35 years with a mean age of 26.06 years. During the study, the experimental subject group was asked to refrain from any systematic or vigorous activity other than that associated with the experiment or with the normal performance of their military duties. The normal subject group was asked to refrain from any contact with the experimental equipment. They were asked to refrain from starting any new systematic or vigorous activity during the course of the study, if they were not currently involved in a training program. Although there was no attempt to control the diet of either the experimental or control group they were asked not to change their diet drastically throughout the study. All test subjects had been medically screened by a physician within the month preceeding the study. Prior to commencing the pre-test, each subject completed the "Par Q, Health Appraisal Form" (Appendix C) in order to provide additional information on lifestyle and exercise habits. All subjects were required to complete the "Consent Form for Exercise Test" and the "Consent Form for Participation in Training Program" (Appendix C).

Testing Sessions

All subjects completed one pre-test and one post-training evaluation test battery. All tests were carried out at the University of Alberta

Physical Education Department and the Research and Training Centre for the Physically Disabled. Prior to the pre-test, a familiarization session was carried out at the Canadian Forces Base. During this meeting, all test subjects were informed of testing and training protocols. Test subjects were familiarized with the test equipment, with the exception of the Cybex II equipment. The bicycle ergometer protocol was introduced. Each subject performed a familiarization ergometer ride in accordance with the test protocol, using a nose clip and a mouthpiece. All other pre-test administration was completed at this time.

The physical activity questionnaire (Par Q) was administered and the "Consent for Participation in a Training Program" and "Consent for Exercise Testing" forms were reviewed and signed by the subjects at this time. Although the control of dietary habits is considered a limitation of this study, test subjects were reminded of the importance of a normal and complete diet. In order to emphasize its importance, each subject was provided with a copy of the Canada Food Guide. The subjects completed a simulated maximal oxygen test. Each subject was issued a test/training advisory (15) (Appendix D). There was a minimum of 48 hours separating the pre-test familiarization and the pre-test. The test batteries included measurement of maximal oxygen consumption on the Beckman Metabolic Measurement Cart[†] and the measurement of maximal knee extension flexion torque and local muscle endurance (LME) on Cybex II[††] at the specific angular velocities. All tests were performed under standardized conditions. The temperature ranged from 22.0 - 25.5° C. Subjects were requested not to smoke, eat, drink coffee or tea, for a

---

[†] Beckman Metabolic Measurement Cart (MMC) (Beckman Instruments, Advanced Technology Operations, Anaheim, California).

[††] Cybex II Dynamometer, Lumex Inc. (Bay Shore, New York, 11779).

period of 1.0 hour prior to testing (Appendix D). They were also advised not to perform vigorous exercise for a period of 48 hours prior to testing. Test schedules were arranged so that each subject was tested at the same relative time of day, pre- and post-treatment (15).

Testing Procedure

Maximal Oxygen Consumption

Oxygen consumption was measured by the Beckman Metabolic Measurement Cart while the subject rode a Monark cycle ergometer. The metabolic cart read-out included expired volume, oxygen consumption in liters per minute and milliliters per kilogram per minute, respiratory quotient, percent oxygen and percent carbon dioxide. Volumes were corrected by the integrated computer system for Standard Temperature and Pressure, dry (STPD) and Body Temperature and Pressure Saturated with water vapour (BTPS). Electrocardiograph (ECG) leads were attached to the subject in addition to the Exersentry† heart rate monitoring device. The measurement of maximal oxygen consumption was carried out in accordance with the Modified McArdle Continuous Bicycle test (16). The test protocol is outlined in Appendix B. The criterion that VO_2max has been achieved was that VO_2 showed an increase of less than 80 ml/min when measured in two consecutive measurements or when the subject could no longer continue due to fatigue. Heart rate was continuously monitored on the Exersentry. Oxygen uptake on the Beckman was monitored every 30 seconds. An ECG trace was recorded continuously for, at least, the last minute of exercise in order to determine and record the individual's maximum heart rate. During the recovery period the subject pedalled with minimal resistance for two to five minutes in order to allow a cool down period. Heart rate was monitored until it had dropped to 100 bpm.

---

† Respironics (HK) Ltd., 38 Hung To Road, Kwon Tong, Kowloon, Hong Kong.

Maximal Knee Extension-Flexion Torque and Endurance on Cybex II

One hour and thirty minutes after the completion of the maximal bike ride, all subjects completed maximal knee extension and flexion of the right leg. Each subject contracted maximally in both directions at an angular velocity of 30° per second and later at 60° per second. Each test was separated by a five minute rest period. Fifteen minutes later the muscular endurance test was completed. All subjects exercised at 180° angular velocity, until 50 percent of the maximal torque was reached. Five submaximal practice trials were permitted to allow the subjects to experience the accommodating resistance. The subject was seated in the chair and was instructed not to hold the sides. Straps were applied just above the ankle to secure the lower leg to the machine and across the thighs to secure the thigh to the chair. The subject then completed extension (starting with knee at 90° and ending with knee at 0°) and flexion (starting with knee at 0° and ending with knee at 90°) movements. All subjects completed warm-up exercises to stretch the quadricep and hamstring muscle groups prior to the testing. Peak torque and rate of fatigue were determined from the chart recordings. Throughout the testing, the subjects were verbally encouraged to extend and flex the knee as fast as possible.

Training

The training program consisted of a circuit of eight exercise stations utilizing Hydra-Gym hydraulic resistive equipment. All of the training equipment was rented from the manufacturer. The training equipment was placed in a training room located in the Firehall at the Canadian Forces Base. The following stations were included in the program:

1. Jump Squat (legs)

2. Bench Press (arms)
3. Adducter/Abducter (hip)
4. Biceps (triceps)
5. Hip Flexion (extension)
6. Upright Row (tricep extension)
7. Unilateral Quadricep (hamstring)
8. Incline Shoulder Press (lateral pull)

The training group performed the exercises in the order as listed, but they were initially permitted to start the program at any station in the circuit. Subsequent workouts commenced at the next station on the list. The exercise stations were organized to alternate upper and lower body exercises. The training subjects were paired and provided with a training card as shown in Appendix E.

Each training pair completed 3 sets at each exercise station. Each subject wore an Exersentry heart rate monitoring device. As one subject exercised, the number of repetitions and the heart rate immediately before and after the exercise bout were recorded. All of the data collection was done by a third individual designated to observe the training session. All work:relief ratios were defined by an exercise music tape which signalled the start of exercise, stop of exercise and the length of the rest periods. For each exercise during the first four weeks, the subjects completed as many repetitions as possible in 20 seconds. This training protocol was followed by a 40 second rest period. After week four the subjects completed as many repetitions as possible in 30 seconds, followed by a 50 second rest.

Individual progression was based on the number of repetitions

completed in the exercise period and in accordance with the manufacturer's recommended schedule (Appendix F). For the first training session, the resistance cylinder selectors were placed at settings "1", "5", and "3" for the three sets of exercise completed at each station. Each repetition was counted and individual performance was recorded on the training card (Appendix E). After each session the individual's results were assessed and new training cards prepared for the next workout indicating the new cylinder setting (i.e., if on station number 1 [Appendix E] cylinder selection "1", "5", and "3", the subject completed 20, 12, and 16 repetitions [Appendix F] during the first workout, the training card would be amended to reflect cylinder selection "2", "6", and "4" for the next workout. This would be carried out for every station in the circuit). After each training session, the training cards were evaluated. This process continued until the subjects reached cylinder selection "6", "6", and "6" or until there was no further improvement. After week four and the increase in work:relief ratio to 30:50 seconds, all resistance selectors were returned to "1", "5", and "3" for the three sets. Individual progression was based on the performance criteria outlined in Appendix F and as previously described.

Prior to the start of the training session, all subjects participated in a 2 minute warm-up period, emphasizing various stretching and calesthenic exercises. The last 30 seconds of the warm-up involved a few repetitions at the starting station of the circuit. These were performed at about half the speed that the subject would use if he were making an all-out effort. Upon completion of the training session the subjects participated in a cool-down period of 5 minutes duration. Everyone was observed until heart rates were below 100 bpm.

The program was carried out over an eight week period with 7 workouts every two weeks performed on an alternate day basis. The investigator supervised all training sessions. The subjects were encouraged to make maximal efforts, by the lively music, by their training partner, and by the tester.

Statistical Analysis

Each dependent variable was analyzed by a 2-way analysis of variance with repeated measures. The University of Alberta Department of Educational Research ANOV 26 program was used for the analysis. The difference between selected means was tested for statistical significance by a Scheffé test on an a priori basis (17, 18).

Pre-training t-tests were completed using the University of Alberta program SPSS (Statistical Package for the Social Sciences) on each of the dependent variables in order to ensure that the two groups were not significantly different before treatment. The level of significance was set at $p < 0.05$.

CHAPTER III

RESULTS

Pre-Program t-Tests

The pre-program t-tests demonstrated that the experimental and normal group pre-test means were not significantly different for any of the dependent variables ($p < 0.05$). The results of the t-tests for a difference between two independent means are contained in Appendix G.

Ventilation Measures

During the pre-test measurement of maximal oxygen uptake (VO_2max), nine normal and ten experimental subjects achieved the primary objective criteria for attainment of VO_2max (i.e., an increase of less than 80 ml/min in VO_2 measurement in two successive measurements). During post-test measurement, eleven normal and twelve experimental subjects achieved this goal. The remainder were considered to have attained VO_2max because they were exhausted and had respiratory exchange ratios greater than unity.

Appendix H provides a summary of the two-way analysis of variance for repeated measures and Scheffé test for pre- and post-test means. Comparing the differences between the means for the experimental and normal group, a 27 percent increase was observed in VO_2max ($p < 0.005$) in the experimental group from pre- to post-test while the normal group experienced no change. The difference between the experimental and normal group was found to be significant at .05 level for post-test means (Appendix H, Figure 1). When the data was normalized, the Δ percentage change was significant ($p < 0.001$). Similar observations (26 percent increase) were noted when the ventilatory data was expressed independent

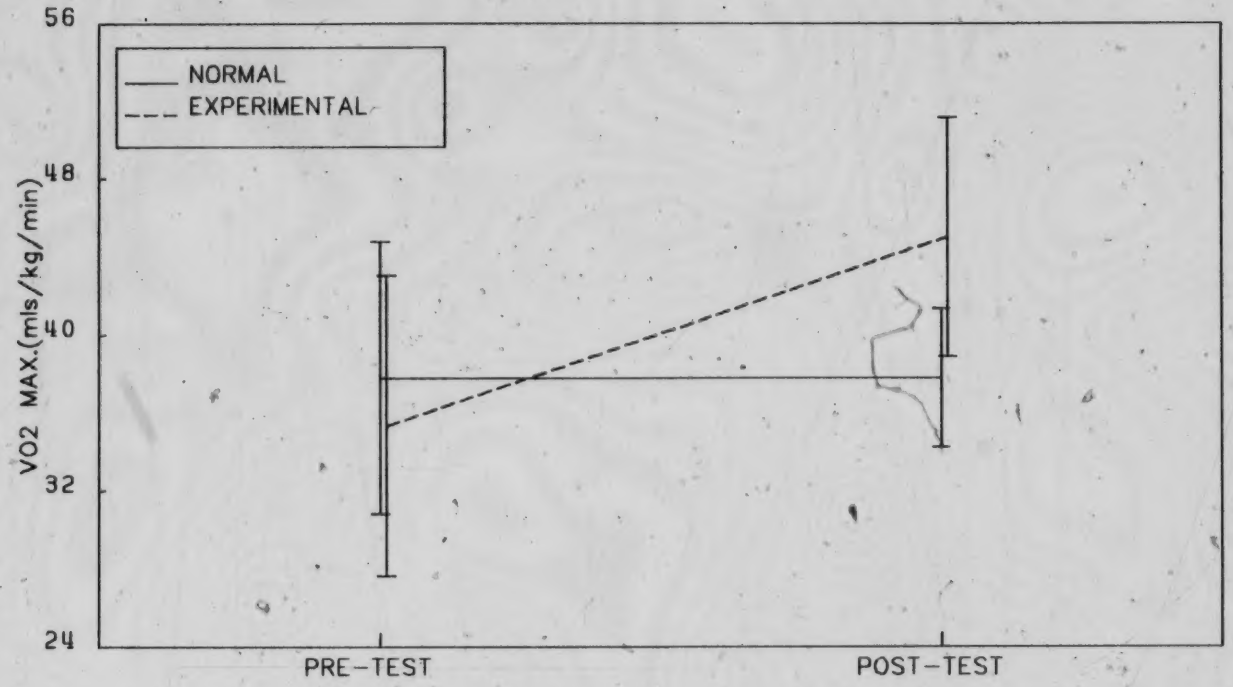

Figure 1. Group means for maximal oxygen uptake (continuous maximal test)

The bars about the means represent ± 1 Standard Deviation

of body weight in liters of oxygen per minute ($p < 0.05$) (Appendix H, Figure 2). The normalized Δ percentage change was significantly different ($p < 0.001$).

In addition, the training program resulted in a 16 percent increase in minute ventilation maximum ($V_E max$) between pre- and post-test. The difference between the post-test means ($p < 0.05$) was found to be significant (Appendix H, Figure 3). The same level of significance was demonstrated when the data was expressed in terms of Δ percentage change.

Heart Rate Responses During Training

During all of the training sessions, the subjects' heart rates were monitored. Heart rate was recorded immediately prior to the commencement of the exercise period and immediately after the exercise bout, on the training card (Appendix E). As a result, heart rate was recorded 48 times throughout the exercise period. In order to compute the percent of maximum heart rate achieved during the training session, the pre-exercise heart rates were averaged with the post-exercise heart rates and divided by the maximum heart rate achieved during the continuous maximal test achieved during pre-test on the ECG. The results were computed after each workout and individual and group results were provided to the training group. Group means for the experimental group are provided in Table 1.

TABLE 1

WEEKLY GROUP MEAN FOR HEART RATE RESPONSE DURING TRAINING FOR THE EXPERIMENTAL GROUP

Total Number of Training Sessions	Group Pre-Test Maximum Heart Rate	Group Percent Maximum Heart Rate Week Number							
		1	2	3	4	5	6	7	8
27	181.61	85.4	82.9	82.4	81.9	82.5	81.8	79.0	80.3

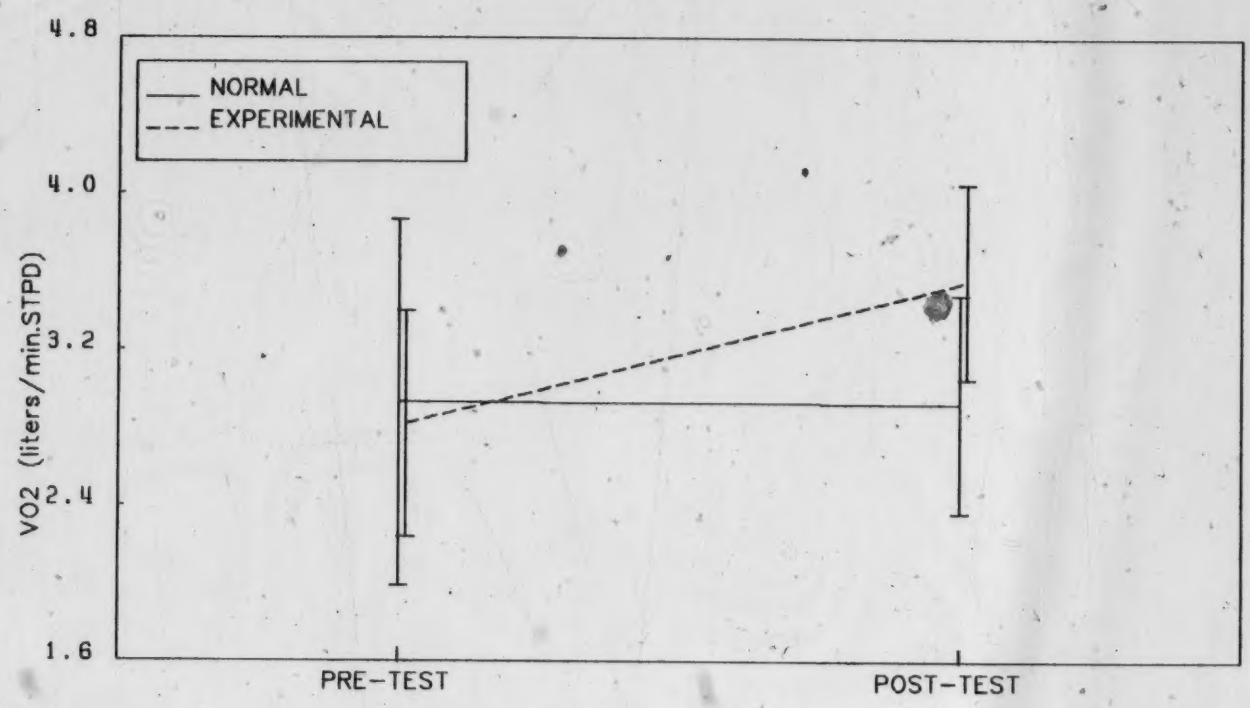

Figure 2. Group means for oxygen uptake (continuous maximal test)

The bars about the means represent ± 1 Standard Deviation

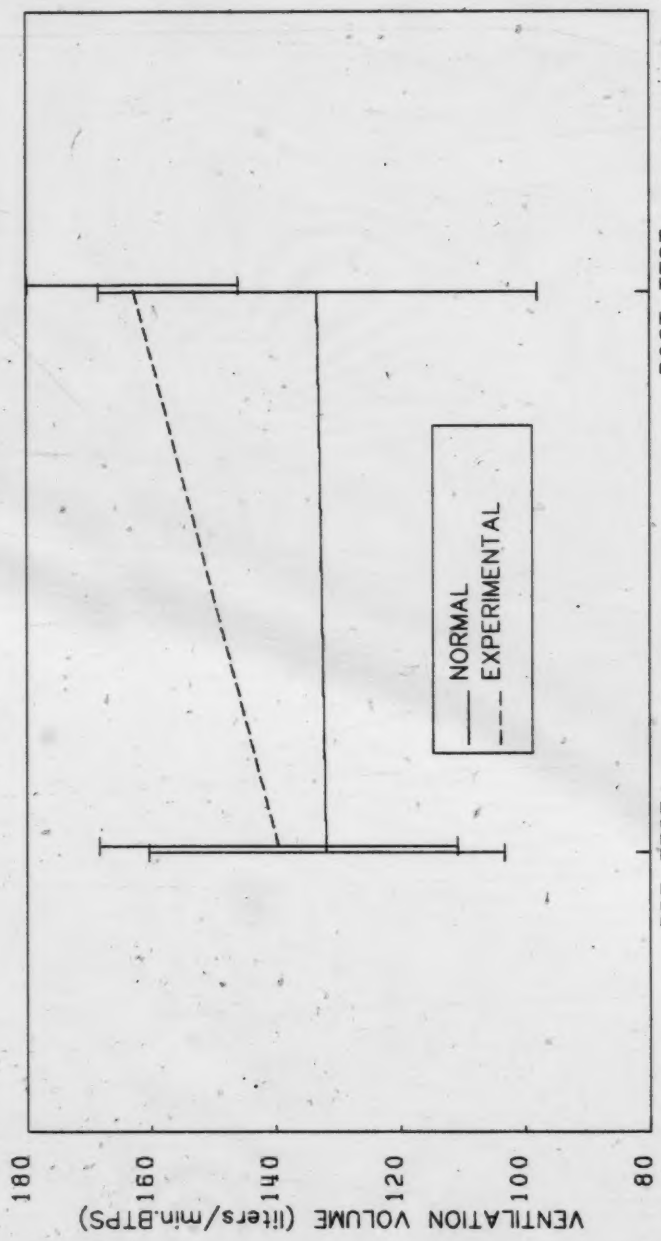

Figure 3. Group means for maximum ventilation volumes (continuous maximal test)

The bars about the means represent ± 1 Standard Deviation

Strength Measures

Muscular strength was measured during maximal knee extension and flexion of the right leg at angular velocities of 30° and 60° per second. The experimental group during extension at 30° per second angular velocity improved their performance by 20 percent ($p < 0.005$) between pre- and post-test while the normal group did not show significant change. The difference between the post-test means for the experimental and normal subjects was significant at the 0.05 level (Appendix H, Figure 4). When the data was normalized, the Δ percentage change was significant ($p < 0.01$).

During flexion at 30°, the experimental group achieved a 23 percent ($p < 0.005$) improvement in strength between pre- and post-test. The normal group achieved comparable results ($p < 0.01$). The post-test means for flexion at 30° were found to be not significantly different for the two groups (Appendix H, Figure 4). When the data was normalized the Δ percentage change was not significant.

With regard to maximal knee extension and flexion at 60° per second angular velocity, the training group experienced a 19 percent ($p < 0.01$) improvement in extension and a 28 percent ($p < 0.001$) improvement in flexion (Appendix H, Figure 5) in pre- to post-test means. The post-test means were found to be not significantly different for the two groups. When the data was normalized, the Δ percentage change was not significant for extension or flexion.

Muscular Endurance Measures

In regard to total work the experimental group demonstrated a 29 percent ($p < 0.001$) improvement in extension and a 35 percent ($p < 0.001$) improvement in flexion. The normal group did not demonstrate significantly different results (Appendix H). The post-test means were found to be not

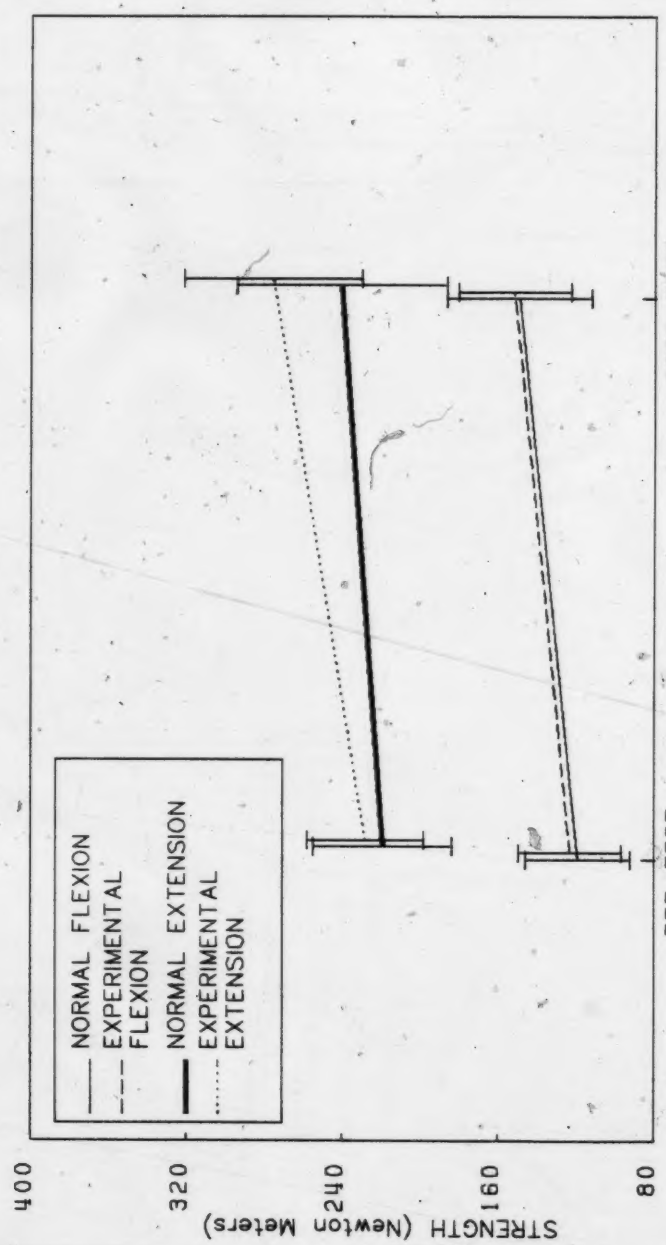

Figure 4. Group means for strength (Cybex 30°)

The bars about the means represent ± 1 Standard Deviation

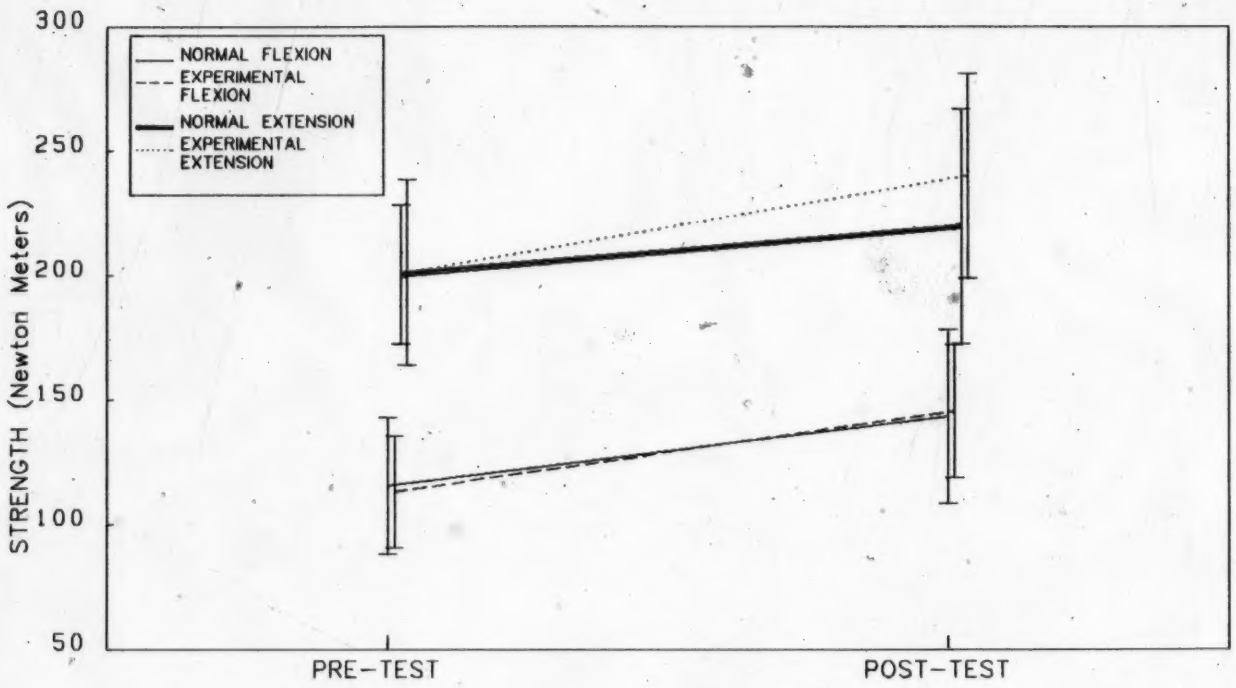

Figure 5. Group means for strength (Cybex 60°)

The bars about the means represent ± 1 Standard Deviation

significantly different for the two groups (Figure 6). When the data for flexion was normalized, the Δ percentage change for flexion was significant ($p < 0.01$) and for extension was not significant.

During the muscular endurance test, the time of exercise was recorded and was used to determine extension and flexion in newton-meters per second. The training group demonstrated a 39 percent ($p < 0.001$) improvement in extension and a 47 percent ($p < 0.001$) improvement in flexion in pre- to post-test. The pre- to post-test means for the normal group were found to be not significant for extension and significant ($p < 0.05$) for flexion. Subsequent Scheffé tests demonstrated significance ($p < 0.05$) for post-test extension and flexion means in relation to time (Appendix H, Figure 7). When the data was normalized, the Δ percentage change for extension and flexion was significant ($p < 0.01$).

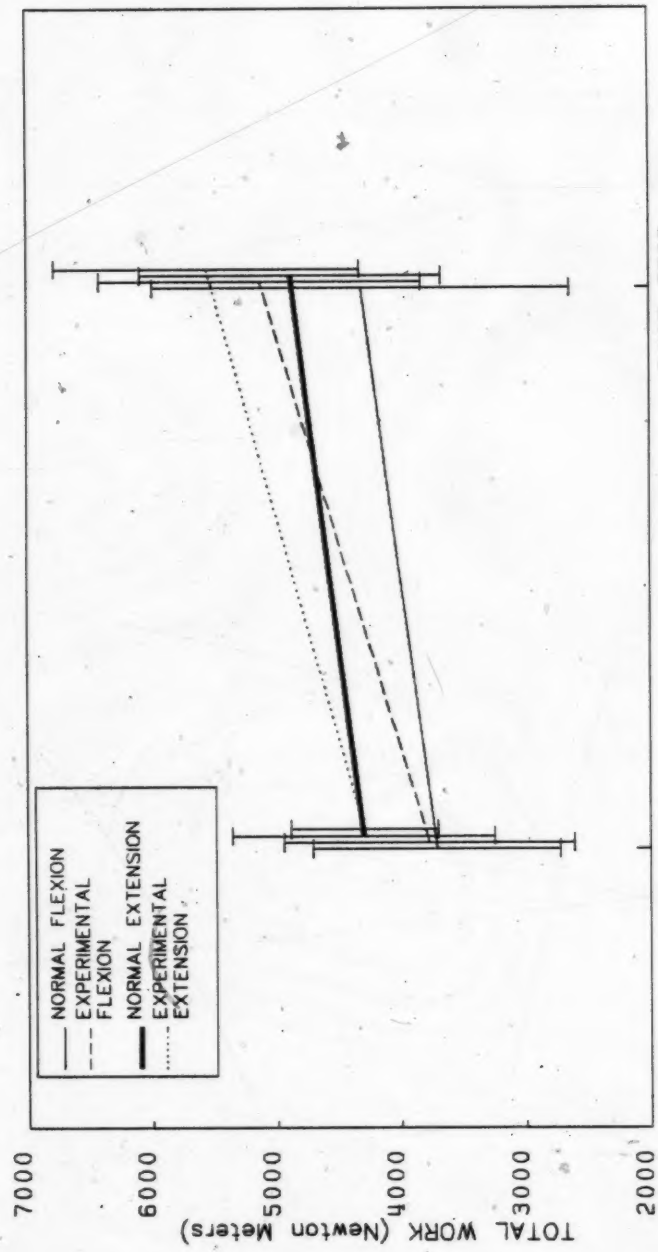

Figure 6. Group means for total endurance work (Cybex 180° to 50 percent drop-off)

The bars about the means represent ± 1 Standard Deviation

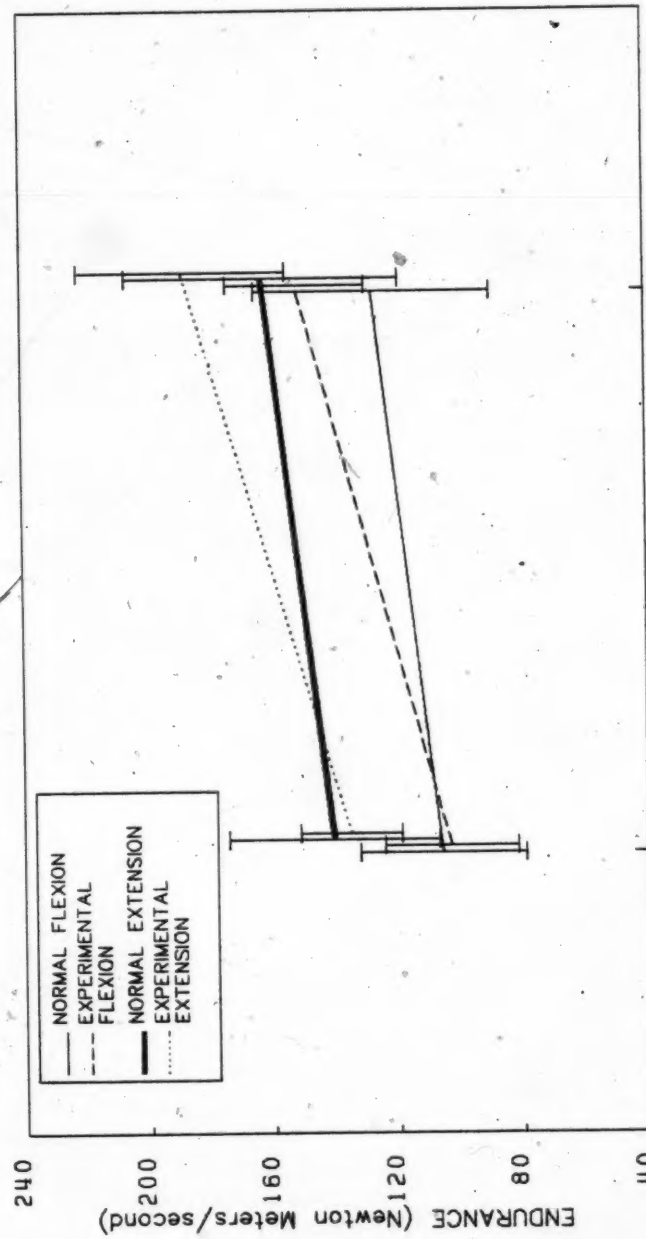

Figure 7. Group means for extension/flexion - newton meters per second (Cybex 180° to 50 percent drop-off)

The bars about the means represent ± 1 Standard Deviation

CHAPTER IV

DISCUSSION

The 15 experimental subjects completed the eight week program without incident. As observed in the results, the training subjects worked at relatively high heart rate intensities throughout the program. The subjects commented on the lack of muscle soreness associated with the training program. Fox (19) has shown that muscular soreness is least following isokinetic contractions. Perrine's (11) observations support these findings:

> An isokinetic exercise does not cause a muscle to contract eccentrically following a concentric contraction; in fact the opposite muscle group can be loaded to its relative maximum on the return movement of a full repetition. Thus, a muscle can relax briefly and receive circulation in between every contraction. This may even produce a pumping effect on circulation and experience indicates that it provides freedom from the muscular ache and lingering weakness commonly developed in uninterrupted contraction exercises. Thus in addition to the potential physiological and metabolic benefits with intermittent contractions, the freedom from discomfort may be important to an incentive for exercising regularly.

Although the investigation of muscle soreness was not a purpose of this study, its absence promoted continued participation by the experimental group. Further research is required to investigate muscle soreness associated with the use of hydraulic resistive equipment.

The experimental group participated in no other physical training activity other than the training program. Although the normal group was asked to refrain from starting any new systematic or vigorous activity during the course of the study, it was observed in the post-test questionnaire that this was not the case. Six members of the normal group were required, by work regulations, to attend fitness classes three times per week throughout the training period. The classes consisted of

fifteen minutes of calesthenics and conditioning and thirty minutes of organized games. Additionally, two of the normal subjects had arrived and reported for work immediately prior to the study. Since they were new members of the work team, they were assigned jobs which involved heavy lifting tasks, such as working in heavy vehicle tire bays. Although these tasks were part of the job routine, there was a great deal of work emphasizing knee extension and flexion.

Ventilatory Responses

Maximum oxygen uptake is the most widely used dependent variable in assessing the magnitude of training effect (20, 21, 22, 23, 24, 25). In the present study, the experimental group demonstrated a 27 percent ($p < 0.005$) improvement from pre- to post-test (9.69 ml/kg/min). These changes are relatively high and even exceed those reported in some running programs, of 15 to 20 percent increase (26, 27, 28).

Using Cybex isokinetic training devices Gettman et al. (29) reported a 3 percent ($p < 0.05$) improvement in aerobic capacity as measured on a treadmill test, after the initial eight weeks of a circuit strength training program. In a subsequent study Gettman et al. (30) demonstrated a 17 percent ($p < 0.05$) improvement in VO_2max as measured on a treadmill test with a group of men involved in circuit weight training (CWT) using Universal Gym Inc. machines. The training subjects were required to run for 30 seconds following each CWT station. A second group was required to do CWT only and showed an improvement of 12 percent ($p < 0.05$) from pre- to post-test.

In a study by Satre (31) the training group showed a 15 percent ($p < 0.001$) increase in aerobic power from pre- to post-test as a result of training for 10 weeks using a variety of Hydra-Gym machines.

In Satre's study, the pre-test group mean was very close to that observed in the present study (35.73 versus 35.3 ml/kg/min). In Satre's study the method of predicted maximal performance was used to measure VO_2max. The accelerated improvement in the present study in regards to post-test VO_2max may be associated with the increased intensity and frequency of training when compared to previous works (29, 30, 31).

Whereas VO_2max provides a relative figure for oxygen uptake in consideration of the subject's body weight, oxygen uptake (VO_2) provides an absolute figure for the measurement of increases in aerobic power. The experimental group demonstrated a 26 percent ($p < 0.05$) increase in VO_2 between pre- and post-test.

Minute ventilation ($V_E$max) increases in pre- to post-test scores for the training group, for the most part, is directly proportional to increases in the amount of oxygen consumed and carbon dioxide produced per minute by the working muscles (32). $V_E$max increased by 16 percent (N.S.)[†] in the experimental group from pre- to post-test; however, the difference between post-test means was significant ($p < 0.05$). The increase in $V_E$max represents a mean difference of 23.3 liters/min^{-1} between pre- and post-tests. Gettman (33) previously reported significant increases in both isotonic and isokinetic maximum pulmonary ventilation. Mean differences of 11.6 and 10.3 liters/min^{-1} between pre- and post-test were reported after 20 weeks of training (33). In contrast, Nagle and Irwin (20) and Butta (34) reported no significant differences pre- to post-test between experimental and control groups in $V_E$max after training with weights for 8 and 6 weeks respectively.

The evidence of the present study strongly suggests that aerobic power can be significantly increased using hydraulic resistive apparatus training. The results of this study were achieved over a shorter duration

[†] Not Significant

than in previous investigations (Gettman [7] - 20 weeks, Gettman [30] - 12 weeks, Satre [31] - 10 weeks) which demonstrated significant improvements. In the present study, the program did not involve any other exercise other than that performed on the equipment. In the study by Gettman (30) which demonstrated the highest previously recorded improvements in VO_2max, the training subjects were required to run for 30 seconds following each CWT station.

The physiological responses that were observed with training on the hydraulic equipment implies that intense work can produce improvements at a faster rate than can other types of equipment studied (7, 10, 20, 29, 30, 33). This may be attributable to the nature of the hydraulic resistive equipment. The equipment permits exercise of both agonistic and antagonistic muscles during the same exercise bout. This type of exercise has been suggested to produce a muscle pumping action which aids the flow of blood to the working muscle, unlike the blood occlusion that occurs during other contractions (19). As a result, acute muscle soreness due to lack of adequate blood flow and delayed soreness which is greatest following eccentric contractions (19) is reduced.

Another factor which may account for the improvements in the ventilatory measures in the present study is the hydraulic resistive equipment's capability allowing the muscles to receive near maximum resistance overload with each repetition. Unlike isokinetic apparatus, the speed of movement is not pre-set on the machine. The hydraulic equipment allows for a self-accommodating resistance which is dependent upon the speed of movement, the user; therefore, achieves a high accommodating resistance overload at the beginning of the set when the muscles are at their peak energy level and also at the end of the set when muscles are fatigued. Thereby an individual should do more work, with less chance

of local muscular fatigue and consequently place greater demands on the cardio-respiratory system than with other types of exercise equipment.

Perhaps the greatest problem interpreting the results of this study and other studies using different types of equipment is equating the total amount of work done or the intensity of the training sessions. In the present study, one method of monitoring intensity was the observation of heart rate responses to the training sessions.

Initially, the primary purpose for monitoring heart rate was to ensure that the subjects were not overly stressed by the training regimen. As the study progressed it became apparent that the subjects were using the devices for self motivation (35) (i.e., improving responses by working harder in order to increase their percent of maximum heart rate in comparison to previous performance and competing against their training partner). The Exersentries became motivating devices that seemed to promote increased intensity in regards to heart rate response to the training.

This type of stimulus coupled with the fact that much larger quantities of high intensity work can be performed intermittently than continuously (21, 36, 37), in the author's opinion, might well be responsible for the major success of the training method used in this study.

Muscular Strength and Endurance

In this study, the measurement of change in muscular strength and endurance was carried out on the right leg during maximal extension and flexion efforts. Moffroid observed that the study of the quadricep muscle group is simpliest: "The muscle has a distinct force variation through a range of motion and one can be relatively assured of correctly observing peak

torque and the point in the range of motion where it occurs. This is not as true for the hamstring muscle group" (38).

Thistle et al. suggested that: "The measurement of torque is the best index of muscular contraction since exercises which involve lifting of weights are difficult to interpret as tests of improvement in training programs" (39). Strength was measured in this study on the Cybex II at angular velocities of 30° per second and 60° per second and peak torque was recorded. At an angular velocity of 30° per second, the experimental group improved 20 percent ($p < 0.005$) during extension and 23 percent ($p < 0.005$) during flexion. The normal group demonstrated comparable improvements. As a result, the post-test means were not significant. The strength results at an angular velocity of 60° per second showed the same tendencies.

Muscular endurance was measured in terms of total work and total work per second at an angular velocity of 180° per second. It was considered to be attained when the subject reached 50 percent of the peak maximal torque achieved at the start of exercise. In terms of total work, the training group improved 29 percent ($p < 0.001$) in extension and 35 percent ($p < 0.001$) in flexion. The normal group did not change significantly. The post-test means were not significantly different.

Muscular endurance was defined by Moffroid (38) as the average power output over a given period of time. It could be quantified in units of newton-meter of work per second. It was concluded that the amount of work done was not as important as the rate at which it was done (38). This supports the theory of Hellebrandt (48) that: "power ($f \times d \times t^{-1}$) is the variable on which the extension of the limits of performance depends". Thusly, the importance of showing improvements

in the rate of doing work was considered to be the most meaningful in expressing the results of this study.

With regards to total work per second, the training group improved 39 percent ($p < 0.001$) in extension and 47 percent ($p < 0.001$) in flexion in pre- to post-test. The normal group did not change in extension but had significant changes ($p < 0.05$) for flexion. Post-test means were significantly different ($p < 0.05$) for flexion and extension for the two groups.

A factor which must be considered in this study is that the normal group made excellent improvements in maximal knee flexion and extension at 30° and 60° per second angular velocity. This may be attributable to their 'normal' activity level, described in the results, and may have contributed to the lack of statistical difference in post-test means on the Scheffé tests.

The normal group was highly motivated to improve their personal level of fitness. Prior to assignment to the experimental or normal groups, several of the subjects indicated that they intended to train whether or not they were selected for the training program. The post-test questionnaire (Appendix C) identified eight normal subjects that either trained or were involved in heavy muscular activity. It is possible that other normal subjects did not identify activities that may have improved their fitness level. This may have occurred as a result of the conflict between the individual's desire to become more fit and the researcher's request to refrain from starting new or systematic or vigorous activity during the course of the study.

The speed of training of the normal and experimental groups in comparison to the speed of testing may advantage the normal group. The members of the normal group that trained regularly during the program

participated in large muscle activity involving slow, static contractions. The experimental test subjects completed repetitions as quickly as possible in the exercise time frame. Although it was not possible to calculate the exact speed of exercise due to the various resistance settings and individual efforts of the subjects, the author estimates that the subjects trained at varying angular velocities with a mean score greater than 120° per second throughout the training period. Moffroid (38) has shown that fast training produced almost the same results at both the high and low velocities, while slow training produced markedly better results at the low velocity. In this study the experimental group showed improvements, however, the choice of test speed (30° and 60° per second) may advantage the normal (slow training) group. Moffroid (38) has shown that low power (low speed, high load) exercise produces greater increases in muscular force only at slow speeds. Perhaps it would be more appropriate to test at higher speeds in order to ensure that training effects achieved during training by the normal group are not advantaged by slow speed tests.

The effect of learning on both normal and experimental pre- to post-test scores may account for part of the improvement shown by both groups. It was not possible to schedule more than one pre- and one post-test session due to the subjects' work schedules. A training session on the test equipment may have provided an opportunity to experience the Cybex II resistance prior to the actual test. As a result, part of the improvement experienced by both groups may be attributed to equipment familiarity associated with pre- to post-test learning.

Since there is little research information available on hydraulic equipment, comparisons will be made with other equipment described in

the literature. Gettman et al. (33) observed a lack of difference between isotonic and slow isokinetic training in their 20 week study at 3 sessions per week. All subjects were tested isotonically and isokinetically for strength gains. In contrast, Rosentswieg and Hinson (41) compared training involving isometric, isotonic and isokinetic contractions using integrated electromyograms. Their analysis was based on the assumption that the exercise mode that caused the greatest intensity of electrical activity in a muscle will produce the greatest training effects. These results were in agreement with Thistle et al. (39): isokinetics was slightly ahead of isotonics with isometrics last. The generalization of these findings other than to electrical activity in the muscle is evident.

Pipes and Wilmore (12) analyzed the effects of an eight week, isokinetic and isotonic training program on strength and other parameters. In their opinion, the results demonstrated a clear superiority of isokinetic training procedures over isotonic procedures relative to strength (12).

The choice of the most appropriate method to strengthen muscle has not been clarified. Atha (42) suggests that: "Differences between methods appear to be swamped by differences within them, for the training effects produced are dominated by the chosen regimen (i.e., by the scheduling of training load, frequency, duration, speed and rests)".

The primary difference between isokinetic equipment and the equipment used in the present study is that the hydraulic equipment speed of movement is not mechanically pre-set but controlled by the individual muscles contractile properties as described previously. The author is in agreement with Atha (42) in that: "The most important property of the strengthening stimulus remains the intensity of the loading on the

muscles". Perhaps the stimulus provided by the hydraulic equipment is most appropriate in that it is not pre-determined by the equipment.

The present study has observed significant improvements in cardio-respiratory and strength parameters following eight weeks of hydraulic apparatus training. Considerable comparative investigation remains to be completed before a full understanding of the mode of training is available.

CHAPTER V

SUMMARY AND CONCLUSIONS

Purpose

The purpose of this study was to examine the effects of an eight week program of circuit training using hydraulic resistive apparatus on VO_2max. A secondary purpose was to observe changes that occur in muscular strength and endurance of the quadricep and hamstring muscle group as a result of the training.

Sample Selection

Volunteer subjects were randomly assigned to either the experimental or normal group. The normal group was requested not to start any new systematic or vigorous activity during the course of the study.

Procedures

All subjects were tested immediately prior to the start of the program and immediately after the end of the eight week training program.

Ventilatory measures were taken during a continuous maximal bicycle ergometer test and measured by the Beckman Metabolic Measurement Cart while exercising on a Monark cycle ergometer. Maximal knee extension-flexion torque and endurance were measured using the Cybex II at angular velocities of 30° and 60° per second to measure strength, and at 180° per second, until 50 percent of the maximal torque value was reached in order to measure functional muscular strength or power.

The training program involved 8 pieces of Hydra-Gym hydraulic resistive equipment and was based on principles of circuit training using intermittent exercises. The subjects trained on alternate days for eight weeks. During the first four weeks the subjects trained with a work:

relief ratio of 20:40 seconds. During the final four weeks of the study, a work:relief ratio of 30:50 seconds was used.

A two-way analysis of variance was used to analyze the data: the rows corresponding to methods (i.e., normal and experimental group) (A); the columns to time intervals (i.e., pre-test, post-test) (B). Scheffé tests were used to compare selected means.

Pre-training t-tests were calculated for the dependent variables to confirm group equivalence. Pre-test means were not significantly different for any of the variables ($p < 0.05$) (Appendix G).

Results

The following results were observed:

1. $\underline{VO_2max}$

   The experimental group showed a 27 percent ($p < 0.005$) increase from pre- to post-test while the normal group did not change. The difference between the training and normal group for post-test means was significant ($p < 0.05$). When the data was normalized, the Δ percentage change for VO_2max was significant ($p < 0.001$).

2. $\underline{VO_2}$

   The experimental group showed a 26 percent improvement ($p < 0.05$). from pre- to post-test while the normal group did not change. The difference between the training and normal group for post-test means was significant ($p < 0.10$) (18). When the data was normalized the Δ percentage change was significant ($p < 0.001$).

3. $\underline{V_E max}$

   The experimental group showed a 16 percent improvement which was not statistically significant. The normal group did not change. The difference between the post-test means was significant ($p < 0.05$).

The normalized data demonstrated the equivalent level of significance.

4. Strength 30° Angular Velocity per Second - Extension

The experimental group improved their performance by 20 percent ($p < 0.005$) from pre- to post-test. The normal group showed no significant change. The difference between post-test means was significant ($p < 0.05$). When the data was normalized, the Δ percentage change was significant ($p < 0.01$).

5. Strength 30° Angular Velocity per Second - Flexion

The experimental group demonstrated a 23 percent ($p < 0.005$) improvement from pre- to post-test. The normal group showed comparable results ($p < 0.01$). The post-test means were not significantly different. When the data was normalized, the Δ percentage range was not significant.

6. Strength 60° Angular Velocity per Second

The training group improved 19 percent ($p < 0.01$) in extension and 28 percent ($p < 0.001$) in flexion from pre- to post test. The normal group did not significantly improve in extension but improved significantly in flexion ($p < 0.001$). The post-test means were found to be not significantly different. When the data was normalized, the Δ percentage change was not significant for extension or flexion.

7. Total Work 180° Angular Velocity per Second - 50 Percent Drop-Off

The experimental group improved 29 percent ($p < 0.001$) in extension and 35 percent ($p < 0.001$) in flexion. The normal group did not change significantly. There was no significant difference between post-test means. When the data was normalized, the Δ percentage change for flexion was significant ($p < 0.05$) and not significant for extension.

8. Total Work per Second

The training group demonstrated a 39 percent ($p < 0.001$) improvement in extension and a 47 percent ($p < 0.001$) improvement in flexion. The post-test means were found to be significantly different ($p < 0.05$) for extension and flexion. When the data was normalized, the Δ percentage changes for extension and flexion were significant ($p < 0.01$).

Conclusions

Within the limits of this study, the following conclusions have been made:

1. Aerobic power can be significantly increased utilizing hydraulic resistive equipment.
2. Knee flexion and extension strength can be significantly improved using hydraulic resistive equipment.
3. Knee flexion and extension endurance can be significantly increased using hydraulic resistive equipment.

Recommendations

Further research is required to expand upon the findings of this study using a variety of exercise and measurement techniques. Subjects with higher initial VO_2max should be observed to determine if comparable results can be achieved. Tests of muscular strength should be carried out at higher angular velocities in order to observe changes in strength associated with training at increased speeds. The lack of muscle soreness throughout the program may be a positive factor in promoting continued activity. Further investigation on the training responses associated with the use of hydraulic resistive equipment is recommended.

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APPENDICES

APPENDIX A

REVIEW OF LITERATURE

APPENDIX A

REVIEW OF LITERATURE

The benefits of weight training programs have been discussed at length in the available literature. Hydraulic resistive apparatus is a relatively new idea and as a result there is little research information available. The literature review, therefore, will consider related areas in order to develop the training program used in this study. Section I reviews studies that deal with acute cardio-respiratory responses to weight training. Section II deals with muscular contraction and training programs. Section III presents considerations in developing a cardio-respiratory training program. Section IV considers intermittent exercise as a method to enhance cardio-respiratory function. The many variations in the cited studies in exercise mode, frequency, duration and intensity make direct study comparisons difficult and should be considered as a limiting factor in their interpretation.

Section I. Cardio-Respiratory Responses to Weight Training

As early as 1950, Capen undertook a research program aimed at determining the effects of systematic weight training on strength, athletic power and on muscular and circulo-respiratory endurance. Capen (43) found that weight training twice per week for three months was as effective in the development of circulo-respiratory endurance as was a program of activity which especially emphasized endurance. The subjects elapsed time for a 300 yard run was used as a criterion measurement of circulo-respiratory endurance. Capen found that the group that trained with weights improved in the 300 yard run by 6.2 percent. Observation of the results indicates that the external validity of this study could

be suspect due to the lack of control exhibited in the selection of the experimental group and the appropriateness of the pre- and post-program tests on which the conclusions were based.

Nagle and Irwin (20) conducted an eight week training program, three days a week, in which the 60 experimental subjects were assigned to either a low repetition high resistance group (LH), or to a high repetition low resistance group (HL). Heart rate, oxygen consumption and ventilation was monitored during pre- and post-tests on a bicycle ergometer. The endurance test was terminated when a heart rate of 180 bpm was attained. Free weights were used in the 13 exercises employed during training, with group LH performing two sets of each exercise for a maximum of five repetitions and group HL two sets of each exercise, with a maximum of five repetitions on the first set and twelve on the second set.

Although both groups improved in oxygen consumption in post-test measurement, the changes were not significant. It was concluded that five to fifteen repetitions per set had no significant effect on oxygen consumption determined during bicycle ergometry (20).

Girandola et al. (8) considered the effects of nine weeks of physical training on aerobic capacity and body composition of 29 college men. Each subject completed circuit training consisting of calisthenics, running and weight training, two days a week. Oxygen uptake, minute ventilation and heart rate were monitored during pre- and post-tests on a bicycle ergometer. Oxygen uptake was calculated for the nine fattest (more than 20 percent fat) and nine leanest (less than 10 percent fat) subjects.

Results of the study showed a 6.4 percent improvement in VO_2max. Analysis of the findings indicated that there was a greater change in

VO_2max for the fat group, in absolute and relative terms. For the lean group, there were no differences among VO_2max values. It was concluded that in assessing cardio-respiratory adaptation of relatively obese persons to physical training, lean body weight should be used as the reference standard.

The results of Butta (34) are in agreement with those of Nagle and Irwin (20). Twenty-seven male subjects performed ten circuit training exercises three times per week for six weeks. Thirty-six seconds were allotted to complete ten to fifteen repetitions, separated by a 90 second rest interval between stations (34). Statistical analysis revealed no significant differences between groups on the pre- and post-test means of predicted VO_2max. Butta (34) concluded that weight training did not result in enhanced endurance capacity as measured on the bicycle ergometer.

Allen et al. (44) examined the effects of cardiovascular training following high sustained heart rates during weight training, using both high resistance and low repetitions. The program was conducted on Universal Gym and the subjects worked for thirty minutes, three times per week for twelve weeks. Work time was 30 seconds with a 60 second rest interval between stations for the completion of three circuits of six exercises. At the last circuit, work was performed to exhaustion. There were no significant changes in VO_2max during arm or leg work following training. The researchers concluded that weight training has no effect on the cardiovascular response to exercise.

Wilmore et al. (10) considered the effects of circuit weight training on 26 male and 23 female subjects. They were divided into experimental and control groups. The subjects exercised for ten weeks, three times per week at 40-55 percent of one repetition maximum (R.M.).

They performed as many repetitions as possible in 30 seconds, followed by a 15 second rest period. The circuit consisted of ten stations on a Universal Gym and three sets of the circuit were performed. The women showed a significant change in VO_2max, while the men did not. Since the men's initial values of VO_2max were 34.4 percent higher than their female counterparts, it was concluded that more intense work may have been required to increase the relatively high VO_2max levels of the males.

Gettman et al. (7) compared 11 male subjects and 14 controls after training three days per week for 20 weeks. The circuit consisted of ten Universal Gym stations, performed in two sets of 15 repetitions with 20 to 25 second rests between exercises. Covariance analysis showed no significant difference in VO_2max expressed relative to lean body weight in the experimental group. The researchers concluded that this type of program produced only a small aerobic effect as measured on the treadmill endurance run.

Hickson et al. (9) considered the effects of heavy resistance training (HRT) on nine male subjects. The subjects completed 3-5 sets, five times per week for ten weeks using a combination of free weights and Universal Gym equipment. All exercises were performed with as much weight as possible and sets were separated by three minute rest intervals. The researchers concluded that HRT is capable of dramatically increasing short term endurance when the muscles involved in the training are used almost exclusively during the testing without an accompanying increase in VO_2max.

In another study by Gettman et al. (30) the physiologic effects of a program of combined running and weight training were compared with a program of circuit weight training. Thirty-six females and 41 males

were assigned to either of the previous groups or to a control group. The training groups participated in a 12 week program, three days per week. Three circuits of ten weight-training exercises were completed with 12-15 repetitions performed in 30 seconds at 40 percent of one repetition maximum at each station. The combined running-weight training group included 30 seconds of running following each weight training station. The combined running and weight training group and circuit weight training group had significant increases in VO_2max, and strength and significant decrease in body fat. The controls did not change.

Table A-1 presents an overview of the findings of training studies of O_2 consumption responses to various forms of weight lifting. The lack of cardio-respiratory adaptation may be attributable to several factors: the training program used, the training program duration, the use of an inappropriate test to measure cardio-respiratory changes, or the type of equipment used and its emphasis on a specific muscular contraction.

Section II. Muscular Contraction and Training Programs

Resistance training programs are modelled around the contractions which predominate. Therefore, programs may be referred to as isometric, isotonic or isokinetic in nature. Each of the training programs has certain advantages and disadvantages. Perhaps the major criticism of isometric training is that it develops strength primarily at the joint angle of training, but less so at other angles (19). Isotonics tend to produce a more uniform development of strength. An isotonic contraction is one in which the muscle shortens while lifting a constant resistance load with the muscular tension varying over the full range

APPENDIX A-1

TRAINING STUDIES OF O_2 CONSUMPTION RESPONSES
TO VARIOUS FORMS OF WEIGHT TRAINING

	Researcher	Date	n	Weeks Trained	Days per Week	Training Program Mode	Method of Measurement	Statistical Difference
1.	Capen	1950	45	12	2	Free Weights	Time on 300 yd Shuttle Run	No Difference
2.	Nagle et al.	1960	60	8	3	Free Weights	VO_2max - Bicycle Ergometer	No Difference
3.	Girandola et al.	1973	29	9	2	Free Weights Running Calisthenics	VO_2max - Bicycle Ergometer	Significant Fat Group No Difference Lean Group
4.	Butta	1973	27	6	3	Free Weights	VO_2max - Bicycle Ergometer	No Difference
5.	Allen et al.	1976	66	12	3	C.W.T. Universal	VO_2max - Cranked or Pedalled Bicycle Ergometer	No Difference
6.	Wilmore et al.	1978	49	10	3	C.W.T. Universal	VO_2max - Walk-Run To Exhaustion Treadmill	Males - No Difference Females - Significant Difference
7.	Gettman et al.	1978	41	20	3	C.W.T. Universal	VO_2max - Running Protocol Treadmill	No Difference
8.	Hickson et al.	1980	9	10	5	H.R.T. Free Weights Universal	VO_2max - 2 Treadmill Tests 2 Bicycle Ergometer	No Difference
9.	Gettman et al.	1982	78	12	3	Universal Running	VO_2max - Treadmill Run	Significant Increase

of joint motion. The heaviest constant load that can be lifted through a full range of joint motion can be no heavier than the weight that can be lifted at the weakest point of the muscle. In A-2 (19) the weakest point of the elbow flexor muscles through a range of motion between 40° and 80° was 48 pounds, and occurred at 40°. Therefore, the heaviest load that can be lifted through that range of elbow flexion is 48 pounds. The muscle is near maximally contracted only at the joint angle of 40°, or at its weakest point. At its strongest point (115° to 120°) the muscle is contracted to only 53 percent of the maximum. This is a definite disadvantage with respect to strength training programs that involve only isotonic contractions using constant loads (19).

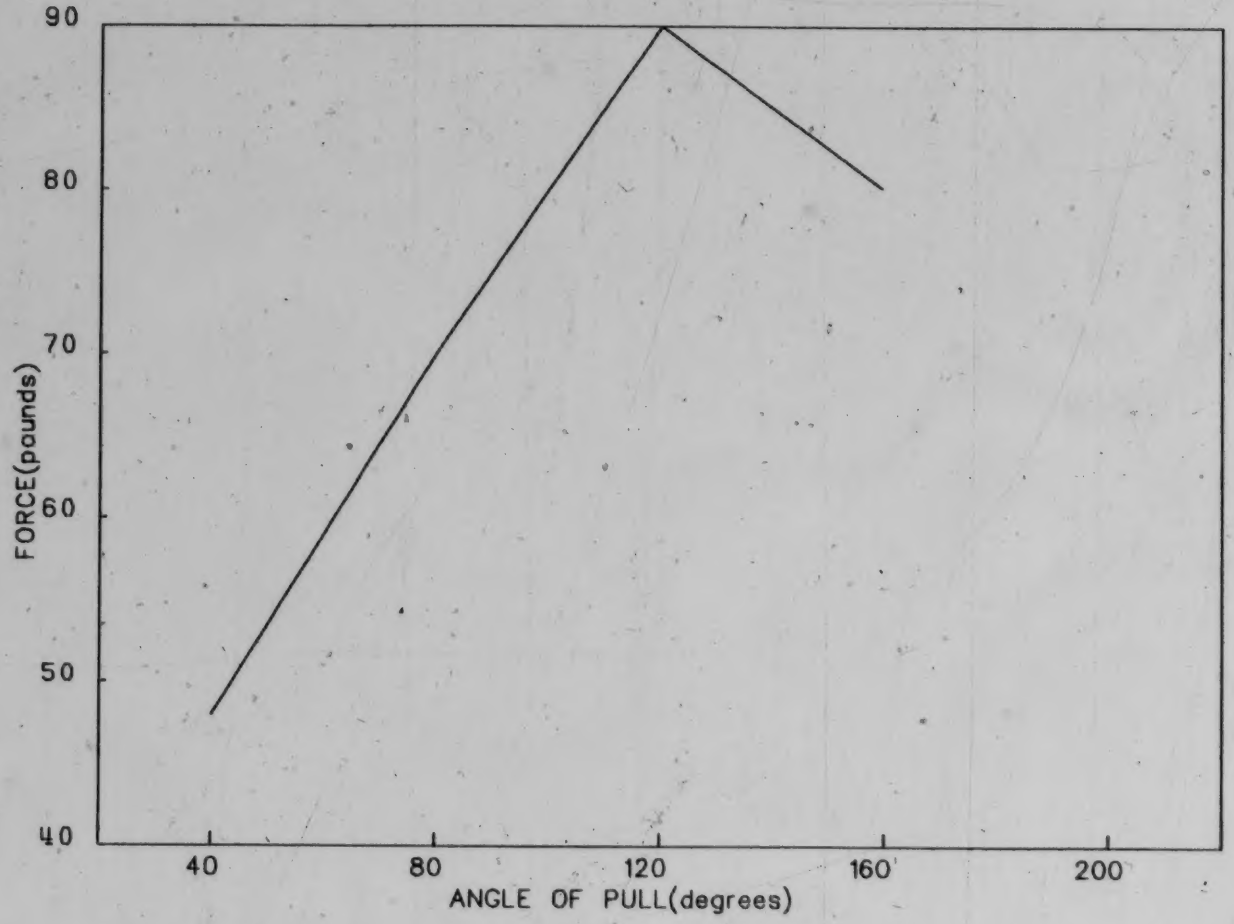
Isokinetic resistance training procedures are significantly better in bringing about changes in muscular strenth, body composition, and motor performance tasks than are standard isotonic resistance training procedures (19). A breakdown of the advantages and disadvantages of isokinetic, isotonic and isometric programs is given in A-3. The type of muscular training with the overall best rating is the isokinetic program. Also there is thought to be the least possibility of injury to the user. This is said to be attributable to accommodating the resistance which varies to match the force being applied throughout the range of motion, such that less resistance always meets less force and greater resistance always meets greater force.

Section III. Development of a Cardio-Respiratory Training Program

The development of cardio-respiratory training programs requires careful consideration of the variables of concern. Wenger et al. (45) reported that the most important independent variables which influence

APPENDIX A-2

FLEXION OF FOREARM AT ELBOW JOINT
(Fox [19])



APPENDIX A-3

SUMMARY OF ADVANTAGES AND DISADVANTAGES OF THE THREE MOST COMMON TYPES OF RESISTANCE TRAINING PROGRAMS
(Fox [3])

Criterion	Comparative Rating		
	Isokinetic	Isometric	Isotonic
Rate of Strength Gain	E	P	G
Rate of Endurance Gain	E	P	G
Strength Gain over Range of Motion	E	P	G
Time per Training Session	G	E	P
Expense	P	E	G
Ease of Performance	G	E	P
Adaptability to Specific Movement Patterns	E	P	G
Least Possibility of Muscle Soreness	E	G	P
Least Possibility of Injury	E	G	P
Skill Improvement	E	P	G
Ease of Progress Assessment	P	G	E

E - Excellent G - Good P - Poor

optimal achievement of training effect during endurance training are exercise intensity, duration, frequency and initial fitness level. Maximum oxygen uptake is the most widely used dependent variable in assessing magnitude of training effect (20, 21, 22, 23, 24, 25). Shephard (46) suggests that there are two possible reasons as to why VO_2max is singled out as the best single measure of cardio-respiratory performance:

1. It is the dominant physiological factor in most activities lasting 1 to 60 minutes, and
2. Activities of this duration are of prime importance to the average person.

Training at intensities relative to VO_2max is considered an effective method of monitoring training of the cardio-respiratory system. Astrand (32) recommended that for an untrained individual, an exercise that demands an oxygen uptake exceeding 50 percent of his or her maximal will, when repeated two or three hours per week, gradually increase VO_2max. He further stated that training at 80 percent of VO_2max may elicit a good training effect (increases in VO_2max of approximately 15 percent). These statements imply that it is necessary to monitor oxygen uptake during exercise; however, this can be very difficult in many situations. As an alternate method, it is possible to monitor heart rate as a method of determining intensity of training (1, 2, 10, 44). Astrand recommended that a heart rate of 195 minus the age in years is a good rule of thumb. Other methods include the Karvonen method (47) or the maximal heart rate method (19, 20). Although the threshold intensity varies among individuals, it has been suggested that training at a heart rate of 60 percent to 85 percent of their maximum heart rate as estimated according to age is appropriate (32, 44, 45, 47, 48).

Exercise duration is important in the development of a program.

The minimum duration required for each training session is controversial (10, 26, 32). A minimum of not less than 20 minutes is often recommended.

Frequency of training is another important determinant in improving cardio-respiratory functioning (7, 49, 50). Pollock et al. (51) demonstrated that maximum oxygen uptake and body composition improvements were superior in a 4-day per week conditioning program as compared to 3 days and 2 days per week programs, where intensity and duration were held constant. Fox et al. (52) found that frequencies between 2 and 5 days per week did not significantly affect gains in aerobic power. In contrast, Gettman et al. (30) demonstrated that a three times per week circuit weight training program produced significant increases in aerobic power. Wilmore et al. (10) selected exercise frequency on the basis of previous experience. Three workouts per week was the maximum frequency for novice weight lifters, as muscle stiffness and soreness are common. Pollock (51) recommended that four workouts per week was superior. However, there was some evidence (30, 32, 52) to support two or three workouts per week if the intensity of the program is sufficient. Thusly, the literature is divergent when considering exercise frequency.

Another factor which must be considered is the length of time over which the subjects trained. Recent research emphasizes a period of ten to twelve weeks (9, 10, 44). Significant increases in aerobic power have been reported in relatively short periods. Wenger et al. (45) reported significant improvement in seven weeks. Gettman et al. (7) have demonstrated significant results after extended periods to 20 weeks. It appears that the magnitude of change varies more with the intensity and frequency of training (25, 45, 50, 51, 53) rather than with the length of the program.

Section IV. Intermittent Exercise

Astrand (32) has demonstrated that intermittent exercise with very short work periods of 30 seconds or less imposes a very severe load upon muscle- and oxygen-transporting organs without the engagement of anaerobic processes leading to any significant elevation of blood lactate. Thusly, it is possible to select the proper workload and work and rest periods in such a manner that the main demand is centered on: 1) muscle strength without a major increase in the total oxygen uptake, 2) aerobic processes without significantly mobilizing anaerobic processes, 3) anaerobic processes without maximal taxation of the oxygen-transporting organs, and 4) both aerobic and anaerobic processes simultaneously.

MacDougall and Sale (54) believe that during the shorter work periods a larger proportion of the total energy requirement comes from the high energy phosphate pool and from oxygen bound to myoglobin, each of which has an opportunity to be partially restored during even a brief 30 second recovery period.

Thusly, it has been demonstrated that intermittent exercise is a viable method to enhance cardio-respiratory function.

Conclusion

Many researchers have studied strength and muscular endurance changes that occur as a result of weight training and other resistance exercise machines. The study of cardio-respiratory adaptation to these training methods has been, for the most part, ignored as a possible means to improve cardio-respiratory efficiency. The selection of the most appropriate exercise duration, frequency and intensity is divergent depending upon the author analyses. Hydraulic resistive apparatus is a relatively new concept in resistance training. Little research has been

carried out on this equipment. The manufacturer claims that there may be practical advantages in conditioning the cardio-respiratory system since anything from low power output with small muscle groups to ultra-high concurrent power outputs with larger muscle groups can be achieved (11).

This study has observed the performance of the equipment over a relatively short training period (eight weeks) using circuit weight training and intermittent exercise. The results support the hypothesis that the magnitude of changes varies more with the intensity and frequency of training (25, 45, 50, 51, 54) rather than with the length of the program.

APPENDIX B

MODIFIED McARDLE CONTINUOUS BICYCLE PROTOCOL

APPENDIX B

MODIFIED McARDLE CONTINUOUS BICYCLE PROTOCOL

1. A Monark bicycle ergometer was pedalled at a rate of 60 revolutions per minute (RPM) paced by a visual auditory metronome.

2. Minute by minute work output was monitored from a microswitch and counter assembly mounted on the frame of the ergometer.

3. The test subject pedalled for two minutes at 1 KP (60 watts) resistance.

4. For the next two minutes, the resistance was 2.5 KP (150 watts) and the load was increased .5 KP (30 watts) every two minutes until there was an increase of less than 80 ml/min in VO_2 measurement in two successive measurements or until the subject could no longer continue due to fatigue.

5. During exercise, expired air was collected, measured for volume and analyzed for O_2 and CO_2 content by the Beckman MMC at 30 second intervals.

6. The bicycle was calibrated after each test in accordance with the Monark bicycle ergometer calibration specifications (55).

APPENDIX C

FORMS UTILIZED FOR THE PROGRAM

CONSENT FORM FOR EXERCISE TEST

I, _____ authorize the said Examiner _____ of the University of Alberta and the Canadian Forces to administer and conduct an exercise fitness test designed to determine my cardio-respiratory capacity, muscular strength and endurance and percent body fat.

I understand that the test for assessing cardio-respiratory capacity will involve performing on a bicycle ergometer at progressively increasing workloads until exhaustion. Throughout this period my heart rate will be monitored using an Exersentry monitoring device. My expired respiratory gases will be measured by the Beckman metabolic measurement cart. Every two minutes during the exercise period the workload will be increased until there is an increase of less than 80 ml/min in VO_2 measurement or until I can no longer continue.

I also understand that for assessing muscular strength and endurance that I will perform maximal knee extension-flexion torque at 60° per second and 180° per second until fifty percent of the maximal torque value is reached. These tests will be performed on the Cybex II testing apparatus.

Percent body fat will be determined using a series of skinfold measurements using Harpenden Calipers.

Every effort will be made to conduct the tests in such a way as to minimize discomfort and risk. However, I understand that just as with other types of fitness tests there are potential risks. These include episodes of transient lightheadedness, fainting, chest discomfort, leg cramps and nausea and extremely rarely, heart attacks.

DATE _____ SUBJECT _____
(signature)

WITNESS _____

CONSENT FORM FOR PARTICIPATION IN A TRAINING PROGRAM

I, _____ give my consent to participate in a training program using hydraulic resistive apparatus. This program has been designed by Wayne Lee.

I understand that I will train on alternate days, seven times every two weeks for a period of eight weeks. During each training session, I will perform three sets on eight exercise stations. During the first four weeks, I will complete as many repetitions as I can in 20 seconds. This will be followed by a 40 second relief interval. During the second four week period, I will complete as many repetitions as possible in 30 seconds followed by a 50 second relief interval. The cylinder resistance setting for each station will be pre-set. However, individual differences will be accommodated based on the number of repetitions that I will complete in the work period. Once a predetermined level is reached, my resistance will be increased.

I acknowledge that I have been fully informed and understand the specific details associated with the training program. I have also been familiarized with the training equipment.

I have been informed that by notice given to the researcher that I may withdraw from this project at any time without prejudice.

I have been informed that all data obtained in this study will be confidential. I will not be identified by name or any other means in summaries, publications or reports based on this study.

I have been informed of potential health risks associated with a program of this nature.

DATE _____ SUBJECT _____
(signature)

WITNESS _____

Physical Activity Readiness Questionnaire (PAR-Q)*

PARTICIPANT IDENTIFICATION

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (√) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE). Translation, reproduction and use in its entirety is encouraged. Modifications by written permission only. Not to be used for commercial advertising in order to solicit business from the public.
Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare

Lifestyle Information Questionnaire

Confidential [A]

Name

Social Insurance Number ▶ (2 … 10)

Your Feelings ▶

1. Here is a list that describes some of the ways people feel at different times. During the past few weeks, how often have you felt

	Often	Sometimes	Never
A. On top of the world?	11 1☐	11 2☐	11 3☐
B. Very lonely or remote from other people?	12 1☐	12 2☐	12 3☐
C. Particularly excited or interested in something?	13 1☐	13 2☐	13 3☐
D. Depressed or very unhappy?	14 1☐	14 2☐	14 3☐
E. Pleased about having accomplished something?	15 1☐	15 2☐	15 3☐
F. Bored?	16 1☐	16 2☐	16 3☐
G. Proud because someone complimented you on something you had done?	17 1☐	17 2☐	17 3☐
H. So restless you couldn't sit long in a chair?	18 1☐	18 2☐	18 3☐
I. That things were going your way?	19 1☐	19 2☐	19 3☐
J. Upset because someone criticized you?	20 1☐	20 2☐	20 3☐

2. Taking things all together, how would you say things are these days — would you say you're

VERY HAPPY	PRETTY HAPPY	NOT TOO HAPPY
▶ 21 1☐	21 2☐	21 3☐

Your Activities The following questions are about some of your work and leisure activities ▶

1. Which of the following best describes how you spent your leisure time during the last two weeks?

(Please check (✓) one box only)

- 22 1☐ Almost all of it by myself
- 22 2☐ A lot of it by myself
- 22 3☐ About half of it by myself and half of it with others
- 22 4☐ A lot of it with others
- 22 5☐ Almost all of it with others

2. During the last two weeks, how many times did you do the following tasks around your home?

2. a. About how much time did you spend on each occasion?

	Times in last two weeks	Minutes usually spent: 1-15	16-30	31-60	>60
Mowing the grass	23 ▶	25 1☐	25 2☐	25 3☐	25 4☐
Shoveling snow	26 ▶	28 1☐	28 2☐	28 3☐	28 4☐
Cleaning floors	29 ▶	31 1☐	31 2☐	31 3☐	31 4☐
Raking leaves	32 ▶	34 1☐	34 2☐	34 3☐	34 4☐
Gardening	35 ▶	37 1☐	37 2☐	37 3☐	37 4☐

Confidential 1 A

Name

Social Insurance Number ▶ 2 10

Your Activities Cont'd ▶

2. Cont'd	Times in last two weeks	2. a. Cont'd 1-15	16-30	31-60	>60
Making beds	11 ▶	13	13	13	13
Caffentry	14 ▶	16	16	16	16
Handyman work, painting	17 ▶	19	19	19	19
Ironing	20 ▶	22	22	22	22
Other (Please specify)	37 ▶	39	39	39	39
23					

Or 45 I did nothing like this in the last two weeks

3. During the last two weeks, how many times did you do any of the following exercises, sports or recreational activities?	Times in last two weeks	3. a. About how much time did you spend on each occasion? Minutes usually spent — 1-15	16-30	31-60	>60
Walking (#Including to and from work or school)	41 ▶	43	43	43	43
Jogging or running	44 ▶	46	46	46	46
Calisthenics	47 ▶	49	49	49	49
Bicycling (including to and from work or school)	50 ▶	52	52	52	52
Bowling	53 ▶	55	55	55	55
Vigorous dancing	56 ▶	58	58	58	58
Skating	59 ▶	61	61	61	61
Skiing (downhill, crosscountry)	62 ▶	64	64	64	64
Curling	65 ▶	67	67	67	67
Racquet sports (tennis, badminton, squash, racquetball)	68 ▶	70	70	70	70
Baseball/Softball	71 ▶	73	73	73	73
Other team sports (hockey, basketball, football, soccer, volleyball)	74 ▶	76	76	76	76
Golf	77 ▶	79	79	79	79
Swimming	80 ▶	82	82	82	82
Other (Please specify)	97 ▶	99	99	99	99
83					

Or 100 I did nothing like this in the last two weeks

APPENDIX D

SUBJECT TEST INSTRUCTIONS

HYDRAULIC RESISTANCE STUDY

TEST/TRAINING ADVISORY

TO: ALL PARTICIPANTS

FROM: WAYNE LEE

Prior to your testing session would you please note the following instructions:

1. Do not smoke within ONE hour of the test/training session.
2. Do not drink coffee or tea (or other beverages containing caffeine) within one hour of your test/training session.
3. Do not eat within one hour of the test/training session. If you cannot avoid eating, please eat lightly.
4. Do not consume any alcoholic beverages within twenty-four hours of your test/training session.
5. Do not exercise strenuously within twenty-four hours of your test/training session.
6. Do be on time for your test/training session, if possible, please be early.

APPENDIX E

TRAINING SESSION PROTOCOL, TRAINING CARD AND EQUIPMENT

TRAINING SESSION PROTOCOL

Frequency: 7 workouts on alternate days every 2 weeks for 8 weeks.
Total of 28 workout sessions.

Duration: Warm-up and cool-down - 10 minutes
Work period - 24-32 minutes

Intensity:
1) as many repetitions as possible in exercise time frame
2) three sets per workout
3) first 4 weeks - 20 seconds work: 40 seconds relief
second 4 weeks - 30 seconds work: 50 seconds relief

Station	Exercise Station	Sets	Exercise	Start	Progression
1	Jump Squat	1	squat action	1	Based on number
		2	squat action	5	of repetitions
		3	squat action	3	
2	Bench Press	1	bench press	1	Increases will occur
		2	bench press	5	in accordance with
		3	bench press	3	Manufacturer's recommendation (i.e.,
3	Adducter/Abducter Hip	1	add/ab	1	20 reps in 20 sec for
		2	add/ab	5	1st set, increase to
		3	add/ab	3	cylinder selection 2)
4	Biceps/Triceps	1	bi/tri	1	
		2	bi/tri	5	
		3	bi/tri	3	
5	Hip Flexion/ Extension	1	hip/flex ext	1	
		2	hip/flex ext	5	
		3	hip/flex ext	3	
6	Upright row/ Tricep Extension	1	upright row/tri	1	
		2	upright row/tri	5	
		3	upright row/tri	3	
7	Unilateral Quad/ Ham	1	uni quad/ham	1	
		2	uni quad/ham	5	
		3	uni quad/ham	3	
8	Incline Shoulder Press/lateral pull	1	inc should press	1	
		2	inc should press	5	
		3	inc should press	3	

TRAINING CARD

NAME _____ DATE _____ MAX H.R. _____

WEEK NUMBER _____ MEAN EX. H.R. _____

TIME _____ % MAX H.R. _____

WORK (SECS) _____ REST (SECS) _____ CARD NO. _____

STN NO.	STATION	SET	CYLINDER SELECTION	EXERCISE	PRE-EXERCISE HEART RATE	NUMBER OF REPETITIONS	POST-EXERCISE HEART RATE
1	JUMP SQUAT	1					
		2					
		3					
2	BENCH PRESS	1					
		2					
		3					
3	ADD/AB HIP	1					
		2					
		3					
4	BICEPS TRICEPS	1					
		2					
		3					
5	HIP FLEXION EXTENSION	1					
		2					
		3					
6	UPRIGHT ROW TRICEPS	1					
		2					
		3					
7	QUAD. HAM.	1					
		2					
		3					
8	SHOULDER PRESS LAT PULL	1					
		2					
		3					

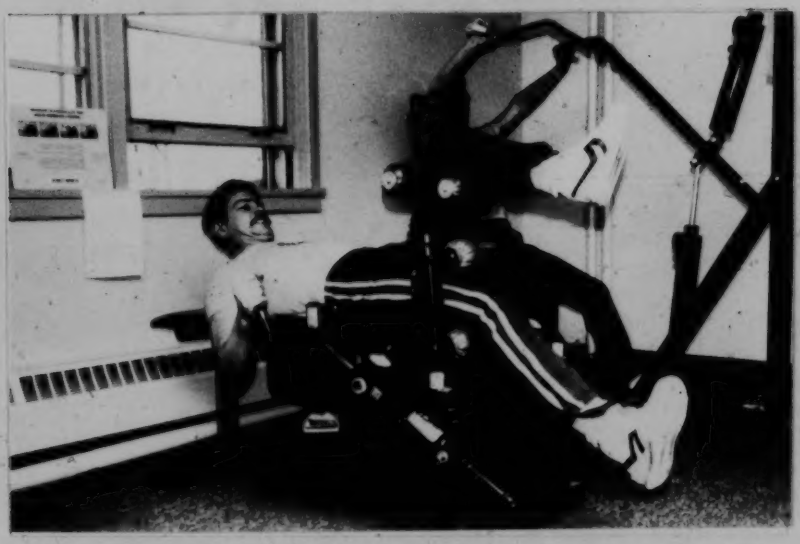
TRAINING EQUIPMENT

1. Jump Squat

2. Bench Press

3. Adducter/Abducter Hip

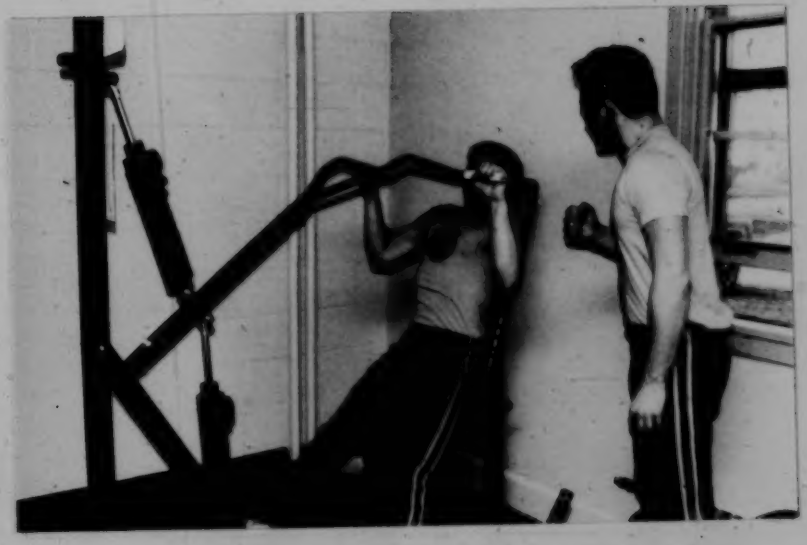
4. Biceps/Triceps



5. Hip Flexion/Extension

6. Upright Row/Triceps

7. Quadriceps/Hamstrings



8. Shoulder Press/Latissimus Dorsi

APPENDIX F

INDIVIDUAL PROGRESSION PERFORMANCE CRITERIA

APPENDIX F

INDIVIDUAL PROGRESSION PERFORMANCE CRITERIA

Method: After each workout, individual performance was assessed and resistance setting amended, based on attainment of pre-selected repetition goals. This process continued as long as the experimental subject performed at pre-selected goals or until maximum cylinder selector ("6") was achieved.

Exercise Station	Start	Increase Cylinder Selector if Repetitions Met or Exceeded	
		20:40 secs	30:50 secs
Jump Squat	1	20	30
	5	12	18
	3	16	24
Bench Press	1	20	30
	5	8	12
	3	14	21
Adducter/Abducter Hip	1	20	30
	5	10	15
	3	15	22
Biceps/Triceps	1	28	42
	5	12	18
	3	20	30
Hip Flexion/Extension	1	36	54
	5	20	30
	3	28	42
Upright Row/ Tricep Extension	1	20	30
	5	8	12
	3	14	21
Unilateral Quad/Ham	1	40	60
	5	20	30
	3	36	48
Incline Shoulder Press/ Lateral Pull	1	20	30
	5	8	12
	3	14	21

APPENDIX G

T-TESTS ON DEPENDENT VARIABLES

SUMMARY OF T-TEST ON PRE-TEST DEPENDENT VARIABLES

Dependent Variable	Degrees of Freedom	t Ratio	Critical t .05
VO_2max	28	1.1	2.048
VO_2	28	1.61	2.048
V_Emax	28	1.00	2.048
Strength 30° Flexion	28	1.00	2.048
Strength 60° Flexion	28	1.21	2.048
Strength 30° Extension	28	1.18	2.048
Strength 60° Extension	28	1.32	2.048
Endurance Total Work Extension	28	0.20	2.048
Endurance Total Work Flexion	28	1.17	2.048
Endurance Total Work/ Second Extension	28	0.278	2.048
Endurance Total Work/ Second Flexion	28	0.270	2.048

APPENDIX H

SUMMARIES OF GROUP MEAN, TWO-WAY ANALYSIS OF VARIANCE, AND SCHEFFÉ TESTS FOR DEPENDENT VARIABLES

APPENDIX-H-1

VO_2MAX SUMMARY

Group Means for Continuous Maximal Test (ml/kg/min, STPD)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	37.800 (± 7.00)	37.807 (± 3.60)
Experimental	15	35.327 (± 7.70)	45.013 (± 6.20)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	1966.375	29			
'A' Main Effects	84.023	1	84.023	1.250	0.27309
Subjects Within Groups	1882.375	28	67.228		
Within Subjects	1049.938	30			
'B' Main Effects	352.324	1	352.324	28.496	0.00001
'A * B' Interaction	351.387	1	351.387	28.421	0.00001
'B' x Subjects Within Groups	346.188	28	12.364		
Within Groups	2228.576	56	39.796		

APPENDIX H-1 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	45.013	37.807	37.800	35.327
45.013	-	0.05	0.05	0.005
37.807	-	-	N.S.	N.S.
37.800	-	-	-	N.S.
35.327	-	-	-	-

N.S. = Not Significant

APPENDIX H-2

VO_2 SUMMARY

Group Means for Continuous Maximal Test (liters/min, STPD)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	2.913 (± 0.94)	2.916 (± 0.56)
Experimental	15	2.817 (± 0.58)	3.552 (± 0.50)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	23.058	29			
'A' Main Effects	1.019	1	1.019	1.295	0.26479
Subjects Within Groups	22.039	28	0.787		
Within Subjects	6.781	30			
'B' Main Effects	1.944	1	1.944	19.979	0.00012
'A * B' Interaction	2.113	1	2.113	21.715	0.00007
'B' x Subjects Within Groups	2.724	28	0.097		
Within Groups	24.763	56	0.442		

APPENDIX H-2 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	3.552	2.916	2.913	2.817
3.552	-	0.10	0.10	0.05
2.916	-	-	N.S.	N.S.
2.913	-	-	-	N.S.
2.817	-	-	-	-

N.S. = Not Significant

APPENDIX H-3

V_EMAX SUMMARY

Group Means for Continuous Maximal Test (liters/min, BTPS)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	131.812 (± 28.5)	133.113 (± 35.2)
Experimental	15	139.513 (± 28.7)	162.811 (± 16.9)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	43385.00	29			
'A' Main Effects	5245.313	1	5245.313	3.851	0.05973
Subjects Within Groups	38139.00	28	1362.107		
Within Subjects	10227.00	30			
'B' Main Effects	2269.00	1	2269.688	10.345	0.00327
'A * B' Interaction	1815.00	1	1815.000	8.273	0.00761
'B' x Subjects Within Groups	6143.00	28	219.393		
Within Groups	44282.00	56	790.75		

APPENDIX H-3 (Continued)

Summary of Scheffé Test for Pre- and Post Test Means

	162.811	139.513	133.812	131.113
162.811	-	N.S.	0.05	0.05
139.513	-	-	N.S.	N.S.
133.812	-	-	-	N.S.
131.113	-	-	-	-

N.S. = Not Significant

APPENDIX H-4

STRENGTH AT 30° PER SECOND - EXTENSION SUMMARY

Group Means for Maximal Knee Extension at a Velocity of 30° Per Second (Newton Meters)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	219.491 (± 35.4)	240.734 (± 54.0)
Experimental	15	228.259 (± 29.8)	275.810 (± 45.4)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	52569.00	29			
'A' Main Effects	3920.625	1	3920.62	2.257	0.14425
Subjects Within Groups	48649.00	28	1737.46		
Within Subjects	10610.00	30			
'B' Main Effects	9052.00	1	9652.50	48.732	0.0000
'A * B' Interaction	1411.87	1	1411.87	7.128	0.01249
'B' x Subjects Within Groups	5546.00	28	198.07		
Within Groups	54195.00	56	967.767		

APPENDIX H-4 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	275.810	240.734	228.259	219.491
275.810	-	0.05	0.005	0.005
240.734	-	-	N.S.	N.S.
228.259	-	-	-	N.S.
219.491	-	-	-	-

N.S. = Not Significant

APPENDIX H-5

STRENGTH AT 30° PER SECOND - FLEXION SUMMARY

Group Means for Maximal Knee Flexion at a Velocity of 30° Per Second (Newton Meters)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	119.328 (± 26.8)	149.522 (± 37.2)
Experimental	15	123.305 (± 26.4)	151.962 (± 28.9)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	25957.68	29			
'A' Main Effects	83.90	1	83.90	0.0091	0.7654
Subjects Within Groups	25873.50	28	924.05		
Within Subjects	8883.50	30			
'B' Main Effects	7063.12	1	7063.12	108.84	0.0000
'A * B' Interaction	5.273	1	5.273	0.081	0.7776
'B' x Subjects Within Groups	1815.31	28	64.00		
Within Groups	27688.81	56	494.44		

APPENDIX H-5 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	151.962	149.522	123.305	119.328
151.962	-	N.S.	0.005	0.005
149.522	-	-	0.05	0.01
123.305	-	-	-	N.S.
119.328	-	-	-	-

N.S. = Not Significant

APPENDIX H-6

STRENGTH AT 60° PER SECOND-EXTENSION SUMMARY

Group Means for Maximal Knee Extension at a Velocity of 60° per Second (Newton Meters)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	200.507 (± 28.1)	219.581 (± 47.2)
Experimental	15	201.230 (± 37.0)	239.921 (± 41.1)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	39487.00	29			
'A' Main Effects	904.68	1	904.68	0.657	0.42161
Subjects Within Groups	38582.00	28	1377.92		
Within Subjects	15304.00	30			
'B' Main Effects	6805.31	1	6805.31	24.702	0.00003
'A * B' Interaction	786.56	1	786.56	2.855	0.10220
'B' x Subjects Within Groups	7714.00	28	275.50		
Within Groups	46296.00	56	826.71		

APPENDIX H-6 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	239.921	219.581	201.230	200.507
239.921	-	N.S.	0.01	0.01
219.581	-	-	N.S.	N.S.
201.230	-	-	-	N.S.
200.507	-	-	-	-

N.S. = Not Significant

APPENDIX H-7

STRENGTH AT 60° PER SECOND-FLEXION SUMMARY

Group Means for Maximal Knee Flexion at a Velocity of 60° per Second (Newton Meters)

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	115.711 (± 27.3)	143.460 (± 34.8)
Experimental	15	113.181 (± 22.5)	145.634 (± 26.6)

Two-Way Analysis of Variance for Releated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	2122.688	29			
'A' Main Effects	3.105	1	3.105	0.041	0.8409
Subjects Within Groups	2119.625	28	75.701		
Within Subjects	1150.375	30			
'B' Main Effects	86.191	1	86.191	2.278	0.14246
'A * B' Interactions	4.512	1	4.512	0.119	0.7324
'B' x Subjects Within Groups	1059.625	28	37.844		
Within Groups	3179.25	56	56.770		

APPENDIX H-7 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	145.634	143.460	115.711	113.181
145.634	-	N.S.	0.001	0.001
143.460	-	-	0.001	0.001
115.711	-	-	-	N.S.
113.181	-	-	-	-

N.S. = Not Significant

APPENDIX H-8

TOTAL WORK - EXTENSION SUMMARY

Group Means for Total Work (Newton Meters) at a Velocity of 180° per Second to 50 Percent Drop-Off

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	4301.9 (± 1049.5)	4879.0 (± 1210.9)
Experimental	15	4294.2 (± 589.9)	5549.4 (± 1227.2)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	-	29			
'A' Main Effects	-	1	895680.00	0.97	0.3315
Subjects Within Groups	-	28	917156.56		
Within Subjects	-	30			
'B' Main Effects	-	1		24.081	0.00004
'A * B' Interactions	-	1	938400.00	3.300	0.07999
'B' x Subjects Within Groups	-	28	284333.68		
Within Groups	-	56	600745.12		

APPENDIX H-8 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	5549.4	4879.0	4301.9	4294.2
5549.4	-	N.S.	0.001	0.001
4879.0	-	-	N.S.	N.S.
4301.9	-	-	-	N.S.
4294.2	-	-	-	-

N.S. = Not Significant

APPENDIX H-9

TOTAL WORK - FLEXION SUMMARY

Group Means for Total Work (Newton Meters) at a Velocity of 180° per Second to 50 Percent Drop-Off

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	3714.8 (± 989.9)	4311.0 (± 1676.0)
Experimental	15	3774.2 (± 1167.6)	5120.9 (± 1290.9)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	-	29			
'A' Main Effects	-	1		1.006	0.32449
Subjects Within Groups	-	28	1041049.62		
Within Subjects	-	30			0.00004
'B' Main Effects	-	1		23.858	0.06952
'A * B' Interactions	-	1	1149609.899	3.562	
'B' x Subjects Within Groups	-	28	322742.813		
Within Groups	-	56	681895.906		

APPENDIX H-9 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	5120.9	4311.0	3774.2	3714.8
5120.9	-	N.S.	0.001	0.001
4311.0	-	-	N.S.	N.S.
3774.2	-	-	-	N.S.
3714.8	-	-	-	-

N.S. = Not Significant

APPENDIX H-10

TOTAL WORK PER SECOND - EXTENSION SUMMARY

Group Means for Extension - Newton Meters per Second

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	140.600 (± 33.6)	162.559 (± 43.7)
Experimental	15	135.020 (± 16.3)	188.264 (± 33.5)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	29051.50	29			
'A' Main Effects	806.95	1	806.95	0.800	0.37873
Subjects Within Groups	28244.12	28	1008.71		
Within Subjects	18913.31	30			
'B' Main Effects	11462.10	1	11462.10	59.158	0.0000
'A * B' Interactions	2026.64	1	2026.64	10.400	0.0031
'B' x Subjects Within Groups	5425.12	28	193.75		
Within Groups	33669.25	56	601.237		

APPENDIX H-10 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	188.264	162.559	140.600	135.020
188.264	-	0.05	0.001	0.001
162.559	-	-	N.S.	0.05
140.600	-	-	-	N.S.
135.020	-	-	-	-

N.S. = Not Significant

APPENDIX H-11

TOTAL WORK PER SECOND - FLEXION SUMMARY

Group Means for Flexion - Newton Meters per Second

Group	n	Pre-Test Mean ± S.D.	Post-Test Mean ± S.D.
Normal	15	105.625 (± 26.7)	127.164 (± 37.7)
Experimental	15	102.881 (± 21.4)	151.829 (± 22.1)

Two-Way Analysis of Variance for Repeated Measures

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Between Subjects	21532.50	29			
'A' Main Effects	980.74	1	980.74	1.336	0.2574
Subjects Within Groups	20551.93	28	733.99		
Within Subjects	14588.15	30			
'B' Main Effects	10133.43	1	10133.43	98.06	0.0000
'A * B' Interactions	1531.69	1	1531.69	14.67	0.0006
'B' x Subjects Within Groups	2923.06	28	104.39		
Within Groups	23475.00	56	419.19		

APPENDIX H-11 (Continued)

Summary of Scheffé Test for Pre- and Post-Test Means

	151.829	127.164	105.625	102.881
151.829	-	0.05	0.001	0.001
127.164	-	-	0.05	0.05
105.625	-	-	-	N.S.
102.881	-	-	-	-

N.S. = Not Significant

APPENDIX I

RAW DATA

APPENDIX I-1

RAW DATA FOR EXPERIMENTAL GROUP

Subject I.D.		Age Years	Weight (kg) Pre-Test	Weight (kg) Post-Test	% Body Fat Pre-Test	% Body Fat Post-Test
Experimental	1	34	78.40	75.90	21.19	19.60
	2	29	88.00	88.63	17.15	15.40
	3	28	67.50	66.27	15.55	15.10
	4	21	79.50	77.00	19.97	16.47
	5	34	99.09	98.60	26.98	26.33
	6	27	68.60	68.00	14.09	14.73
	7	19	66.13	63.63	13.69	10.80
	8	25	64.54	64.90	10.02	12.20
	9	35	79.54	79.50	23.78	20.97
	10	19	85.00	82.70	23.39	24.70
	11	23	89.00	88.09	23.42	17.60
	12	32	65.90	64.50	15.90	13.60
	13	25	94.09	95.45	25.49	25.90
	14	28	97.27	91.81	18.14	14.93
	15	29	98.63	93.63	23.12	20.50
MEAN ± S.D.		27.47 ± 5.4	81.41 ± 12.7	79.91 ± 12.4	19.46 ± 5.0	17.92 ± 4.9

APPENDIX I-2

RAW DATA FOR NORMAL GROUP

Subject I.D.	Age Years	Weight (kg) Pre-Test	Weight (kg) Post-Test	% Body Fat Pre-Test	% Body Fat Post-Test
Normal 1	26	66.50	65.45	11.82	7.83
2	33	67.27	65.00	23.24	23.10
3	25	79.77	76.36	16.53	15.36
4	23	58.63	58.63	9.27	10.98
5	19	89.08	89.54	22.96	24.08
6	31	68.60	68.18	21.15	21.38
7	25	82.72	83.60	14.38	16.79
8	21	72.27	78.18	14.82	13.65
9	32	75.45	75.45	22.90	21.70
10	21	98.00	95.90	16.79	17.20
11	20	70.45	72.72	14.61	14.83
12	21	87.27	90.90	25.93	27.62
13	22	78.18	78.20	17.54	18.79
14	20	71.80	71.36	11.56	13.57
15	31	86.13	87.27	24.73	25.67
MEAN ± S.D.	24.67 ± 4.9	76.81 ± 10.4	77.12 ± 10.7	17.88 ± 5.3	18.17 ± 5.7

APPENDIX I-3

RAW DATA FOR MAXIMAL WORK MEASURES FOR EXPERIMENTAL GROUP

Subject I.D.		Heart Rate (beats/min)		Ventilation (liters/min) BTPS		Maximal VO_2 (liters/min) STPD		VO_2max (ml/kg/min) STPD	
		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Experimental	1	187	188	198.91	191.85	3.26	3.79	42.4	50.0
	2	181	187	163.04	169.33	3.28	4.10	37.3	46.3
	3	167	167	106.87	174.39	2.54	3.32	37.7	50.2
	4	193	182	151.80	184.43	4.32	4.14	54.4	53.8
	5	188	207	111.90	165.00	2.47	3.54	25.0	35.9
	6	176	176	153.50	180.57	2.61	3.32	38.2	48.8
	7	176	182	126.24	136.62	2.32	3.10	35.2	48.8
	8	188	193	129.64	144.81	2.18	2.66	33.9	41.1
	9	176	181	78.76	149.47	1.77	2.95	22.8	37.1
	10	188	188	122.23	135.11	3.16	3.68	37.2	44.5
	11	187	188	162.18	160.16	3.26	3.82	36.7	43.4
	12	200	182	159.79	161.08	2.63	3.33	40.0	51.7
	13	177	181	141.49	155.01	2.93	3.70	31.2	38.9
	14	194	188	148.91	175.74	3.05	4.57	31.4	49.8
	15	147	160	137.34	158.60	2.62	3.26	26.6	34.9
MEAN ± S.D.		181.67 ± 12.9	183.33 ± 10.8	139.51 ± 28.7	162.81 ± 16.9	2.82 ± .58	3.55 ± .5	35.33 ± 7.7	45.01 ± 6.2

APPENDIX I-4

RAW DATA FOR MAXIMAL WORK MEASURES FOR NORMAL GROUP

Subject I.D.		Heart Rate (beats/min) Pre-Test	Heart Rate (beats/min) Post-Test	Ventilation (liters/min) BTPS Pre-Test	Ventilation (liters/min) BTPS Post-Test	Maximal VO_2 (liters/min) STPD Pre-Test	Maximal VO_2 (liters/min) STPD Post-Test	VO_2max (ml/kg/min) STPD Pre-Test	VO_2max (ml/kg/min) STPD Post-Test
Normal	1	178	181	103.37	103.56	2.22	2.40	34.0	36.7
	2	167	176	98.12	124.67	1.85	2.44	30.0	37.0
	3	176	176	141.45	109.45	2.81	2.82	35.2	36.8
	4	178	169	81.13	71.54	2.20	2.13	37.6	36.5
	5	200	176	168.30	174.33	2.94	3.15	33.0	35.2
	6	167	187	109.70	102.03	2.20	2.36	32.1	34.7
	7	200	200	179.31	181.97	3.19	3.08	37.5	36.9
	8	186	188	132.10	139.62	2.60	3.23	36.0	41.4
	9	176	176	141.66	174.10	2.91	2.75	38.7	36.5
	10	207	207	174.52	190.20	5.73	4.23	58.5	44.1
	11	188	167	128.37	134.56	2.63	3.10	37.4	42.8
	12	188	188	136.70	152.83	4.10	3.80	47.2	41.9
	13	197	194	120.21	112.15	3.05	2.54	39.0	32.5
	14	171	176	114.35	98.57	2.74	2.88	38.2	40.5
	15	176	169	147.89	127.13	2.80	2.83	32.6	32.9
MEAN ± S.D.		183.67 ± 12.7	182.00 ± 11.8	131.81 ± 28.5	133.11 ± 35.2	2.93 ± .94	2.92 ± .56	37.80 ± 7.0	37.81 ± 3.6

APPENDIX I-5

RAW DATA FOR STRENGTH TEST MEASURES (NEWTON METERS)
FROM CYBEX II FOR EXPERIMENTAL GROUP

		Flexion 30°		Extension 30°		Flexion 60°		Extension 60°	
Subject I.D.		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Experimental	1	109.8	143.7	204.8	241.4	99.0	135.6	168.1	183.1
	2	151.9	181.7	244.1	264.4	146.4	172.2	252.2	244.1
	3	104.4	142.4	195.3	211.5	115.3	142.4	181.7	208.8
	4	172.2	198.0	252.2	329.5	132.9	192.6	230.5	278.0
	5	135.6	130.2	252.2	345.8	130.2	130.2	233.2	292.9
	6	118.0	132.9	238.7	276.6	123.4	135.6	217.0	235.9
	7	100.3	127.5	219.7	235.9	100.3	141.0	195.3	189.8
	8	88.1	111.2	217.0	280.7	71.9	101.7	169.5	260.4
	9	89.5	118.0	181.7	248.1	77.3	105.8	158.7	206.1
	10	134.2	166.8	214.2	244.1	109.9	158.7	207.5	233.2
	11	138.3	181.7	284.8	355.3	122.0	164.1	260.4	306.5
	12	108.5	141.0	206.1	241.4	103.1	132.9	137.0	200.7
	13	97.6	130.2	195.3	233.2	100.3	122.0	169.5	198.0
	14	162.7	195.3	265.8	317.3	151.9	173.6	240.0	284.8
	15	138.3	179.0	252.2	311.9	113.9	176.3	198.0	276.6
MEAN ± S.D.		123.3 ± 26.4	152.0 ± 28.9	228.3 ± 29.8	275.8 ± 45.4	113.2 ± 22.5	145.6 ± 26.6	201.2 ± 37.0	239.9 ± 41.1

APPENDIX I-6

RAW DATA FOR STRENGTH TEST MEASURES (NEWTON METERS)
FROM CYBEX II FOR NORMAL GROUP

		Flexion 30°		Extension 30°		Flexion 60°		Extension 60°	
Subject I.D.		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Normal	1	100.3	108.5	189.8	214.2	93.6	93.6	173.6	206.1
	2	94.9	105.8	157.3	155.9	94.9	103.1	150.5	138.3
	3	131.5	180.3	252.2	309.2	99.0	155.9	212.9	282.0'
	4	82.7	119.3	179.0	173.6	86.8	108.4	226.5	162.7
	5	158.7	219.7	253.6	317.3	147.8	200.7	212.9	282.0
	6	81.4	84.1	154.6	187.1	92.2	99.0	149.2	180.3
	7	141.0	147.8	219.7	208.8	130.2	146.4	191.2	179.0
	8	138.3	155.9	230.5	238.7	141.0	149.2	199.3	218.3
	9	93.6	131.5	207.5	197.8	86.8	147.8	187.1	188.5
	10	165.4	200.7	249.5	339.0	180.3	210.2	253.6	306.5
	11	115.3	149.2	210.2	240.0	111.2	142.4	199.3	252.2
	12	113.9	162.7	252.2	276.6	108.5	154.6	211.5	235.9
	13	139.7	157.3	252.2	240.0	124.8	147.8	212.9	222.4
	14	100.3	135.6	230.5	238.7	100.3	118.0	198.0	207.5
	15	132.9	184.4	253.6	273.9	138.3	174.9	229.2	231.9
MEAN ± S.D.		119.3 ± 26.8	149.5 ± 37.2	219.5 ± 35.4	240.7 ± 54.0	115.7 ± 27.3	143.5 ± 34.8	200.5 ± 28.1	219.6 ± 47.2

APPENDIX I-7

RAW DATA ENDURANCE TEST MEASURES (50 PERCENT DROP-OFF)
FROM CYBEX AT 180° PER SECOND FOR EXPERIMENTAL GROUP

		FLEXION PRE-TEST		FLEXION POST-TEST		EXTENSION PRE-TEST		EXTENSION POST-TEST	
Subject I.D.		Total Work Newton-Meter	Newton-Meter/ Second	Total Work Newton-Meter	Newton-Meter/ Second	Total Work Newton-Meter	Newton-Meter/ Second	Total Work Newton-Meter	Newton-Meter/ Second
Experimental	1	4047.7	111.2	5776.6	151.2	4369.0	115.6	7029.5	204.3
	2	3498.5	133.0	3807.6	144.2	3620.5	144.8	4849.1	164.9
	3	5093.1	99.9	5239.6	145.5	4556.2	115.1	4751.4	132.7
	4	2920.8	103.6	3921.6	156.9	3669.3	139.0	4784.0	185.4
	5	4775.8	115.9	6362.4	163.1	4426.0	133.3	6411.2	234.0
	6	2034.0	86.9	4702.6	146.0	4084.3	127.2	5499.9	163.7
	7	4718.9	92.2	5630.1	159.9	4474.8	135.6	5630.1	236.6
	8	2676.7	79.4	3498.5	137.7	3579.8	124.7	4605.0	205.6
	9	2253.7	56.9	3628.7	107.4	3856.5	117.6	4263.3	154.5
	10	5687.1	129.3	8005.8	211.8	5402.3	169.9	8559.1	232.6
	11	4995.5	128.1	6687.8	157.0	4979.2	166.0	6964.4	211.0
	12	3197.4	96.5	4621.2	144.4	5264.0	138.9	4588.7	149.0
	13	2302.5	84.3	6020.6	135.0	3596.1	142.1	5613.8	169.1
	14	4165.6	126.2	4152.1	147.2	4133.1	127.6	4181.9	168.6
	15	4244.3	99.9	4759.6	170.0	4401.6	128.0	5510.8	212.0
MEAN ± S.D.		3774.2 ± 1167.6	102.9 ± 21.4	5120.9 ± 1290.0	151.8 ± 22.1	4294.2 ± 589.9	135.0 ± 16.3	5549.4 ± 1227.2	188.3 ± 33.5

APPENDIX I-8

RAW DATA ENDURANCE TEST MEASURES (50 PERCENT DROP-OFF) FROM CYBEX AT 180° PER SECOND FOR NORMAL GROUP

Subject I.D.		FLEXION PRE-TEST		FLEXION POST-TEST		EXTENSION PRE-TEST		EXTENSION POST-TEST	
		Total Work Newton-Meter	Newton-Meter Second	Total Work Newton-Meter	Newton-Meter/ Second	Total Work Newton-Meter	Newton-Meter/ Second	Total Work Newton-Meter	Newton-Meter Second
Normal	1	3465.9	108.3	2359.4	95.9	3823.9	125.8	4119.5	160.9
	2	3376.4	95.9	2196.7	104.6	3688.3	106.2	4196.8	120.6
	3	4059.9	140.0	5451.1	175.8	5019.9	188.7	5841.6	245.4
	4	2798.8	92.1	2213.0	110.6	3221.9	117.6	3343.9	107.9
	5	5295.2	154.8	7094.6	192.8	5565.0	198.7	7647.8	242.0
	6	1643.5	49.5	2652.3	95.4	2603.5	77.0	4108.7	127.6
	7	5085.0	114.52	6191.5	133.4	6069.5	124.9	5573.2	154.8
	8	4116.8	133.6	5565.0	135.7	4287.7	134.8	4458.5	143.8
	9	2920.8	101.8	4002.9	97.2	4100.5	125.0	4352.8	131.1
	10	4661.9	134.0	5190.8	189.4	3750.7	183.0	5190.8	225.7
	11	4816.5	103.8	5386.0	120.8	5727.7	162.7	5247.7	174.9
	12	3929.7	100.2	5093.1	150.7	2717.4	147.7	4474.8	141.6
	13	3482.2	88.4	2473.3	88.3	4230.7	136.5	4450.4	173.8
	14	3075.4	67.7	3034.7	71.2	4865.3	116.4	3311.4	125.4
	15	2994.0	119.8	5760.3	145.5	4857.2	167.5	6866.8	162.7
MEAN ± S.D.		3714.8 ± 989.9	105.6 ± 26.7	4311.0 ± 1676.0	127.2 ± 37.7	4301.9 ± 1049.5	140.6 ± 33.6	4879.0 ± 1210.9	162.6 ± 43.7

APPENDIX I-9

GIRTH MEASUREMENTS FOR ALL SUBJECTS IN THE EXPERIMENTAL GROUP (CM)

		Chest		Abdomen		Gluteal		Thigh	
Subject I.D.		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Experimental	1	104.0	106.0	89.5	84.5	99.5	96.0	59.5	61.0
	2	104.5	108.5	89.5	86.0	102.0	100.5	63.5	65.5
	3	92.5	94.5	82.0	77.5	94.5	94.5	56.0	58.0
	4	98.0	102.5	81.5	79.0	99.0	97.5	61.0	61.5
	5	115.0	117.5	110.0	107.5	112.0	112.0	65.5	65.5
	6	97.0	100.0	79.5	78.5	96.0	93.5	54.0	56.5
	7	87.5	93.5	74.0	73.5	87.0	88.5	54.0	53.5
	8	94.5	99.5	75.5	76.0	90.5	90.0	54.0	56.5
	9	99.5	103.5	88.0	87.0	99.5	99.0	66.5	66.0
	10	96.0	99.0	84.5	82.0	104.0	102.0	60.0	64.5
	11	105.0	111.0	91.5	88.5	101.5	99.0	62.0	63.0
	12	94.0	97.0	76.5	73.5	89.5	89.5	52.5	56.0
	13	112.0	118.0	104.5	102.0	112.0	108.0	67.0	69.0
	14	105.5	111.0	86.0	81.5	108.0	102.0	68.5	66.0
	15	110.0	116.0	101.0	97.0	111.0	105.5	64.5	64.5
MEAN ± S.D.		101.0 ± 7.8	104.9 ± 8.1	87.6 ± 10.7	84.93 ± 10.2	100.47 ± 8.1	98.50 ± 6.8	60.57 ± 5.4	61.8 ± 4.7

APPENDIX I-10

GIRTH MEASUREMENTS FOR ALL SUBJECTS IN THE NORMAL GROUP (CM)

		Chest		Abdomen		Gluteal		Thigh	
Subject I.D.		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Normal	1	94.5	94.5	78.5	78.0	92.5	90.5	51.5	54.0
	2	96.0	95.5	90.5	91.0	96.0	94.0	55.5	57.0
	3	98.0	97.5	83.0	79.5	98.5	95.5	63.0	60.5
	4	85.5	87.5	70.0	71.0	86.5	87.0	51.0	50.0
	5	101.5	102.0	91.0	89.5	106.5	105.0	67.5	64.0
	6	94.0	93.5	84.0	84.0	93.5	92.5	54.0	53.5
	7	96.0	97.5	82.5	84.0	103.0	102.5	59.4	59.0
	8	99.5	101.0	80.5	82.0	96.0	96.0	60.0	59.0
	9	103.0	101.0	86.5	87.5	99.5	98.0	61.5	60.0
	10	103.0	103.5	89.5	88.0	110.0	105.0	66.0	62.5
	11	95.5	93.5	78.5	78.5	92.5	93.0	53.0	54.5
	12	112.0	117.0	96.5	101.0	102.5	105.0	65.0	66.0
	13	96.0	101.0	78.5	79.5	102.0	100.5	63.5	62.0
	14	90.5	90.5	79.0	79.0	96.0	95.5	59.0	58.5
	15	103.0	104.0	90.0	91.0	102.5	99.5	59.5	59.5
MEAN ± S.D.		97.87 ± 6.2	98.63 ± 7.0	83.9 ± 6.8	84.23 ± 7.3	98.5 ± 6.1	97.3 ± 5.6	59.3 ± 5.3	58.67 ± 4.3